Appendix L
Final Focused Feasibility Study Report, Upper Basin of the Coeur d'Alene River, Bunker Hill Mining and Metallugical Complex Superfund Site, Appendix A: Groundwater Modeling Analysis (August 1, 2012)

FINAL

Focused Feasibility Study Report

Upper Basin of the Coeur d'Alene River, Bunker Hill Mining and Metallurgical Complex Superfund Site

Volume 3

Appendices A through D

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Acronyms and Abbreviations

bgs	below ground surface
Box	Bunker Hill Box
cfs	cubic feet per second
CIA	Central Impoundment Area
CTP	Central Treatment Plant
feet/day	feet per day
FFS	Focused Feasibility Study
ft/ft	foot per foot
lb/day	pound(s) per day
mg/L	milligram(s) per liter
msl	mean sea level
NM	not measured
O&M	operation and maintenance
OU	Operable Unit
PEST	parameter estimation
REF	remedial effectiveness factor
RMS	root mean squared error
ROD	Record of Decision
SFCDR	South Fork of the Coeur d'Alene River
SVNRT	Silver Valley Natural Resource Trust
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

APPENDIX A

Groundwater Modeling Analysis

A.1 Introduction

From 2002 to 2005, the National Academy of Sciences (NAS) performed an independent evaluation of the Record of Decision (ROD) for Operable Unit 3 (OU 3) at the Bunker Hill Mining and Metallurgical Complex Superfund Site (NAS, 2005). The study concluded that although adequate characterization of the extent of metals contamination in soil, sediments, and surface water was presented, the major source of dissolved metals to the surface water system—groundwater discharge—was not adequately characterized or fully addressed. In response to these concerns, it was determined by the U.S. Environmental Protection Agency (USEPA) that it was necessary to develop a quantitative tool that could be used to evaluate the spatially varying components of the water budget and dissolved metals loading budget. Two numerical groundwater flow models were developed for the Canyon Creek Watershed (CH2M HILL, 2007) and the South Fork of the Coeur d'Alene River (SFCDR) Watershed (CH2M HILL, 2009b) to better characterize the distribution of dissolved metals loading from the groundwater system under current conditions, and to evaluate various potential remedial actions. Specific objectives of the groundwater modeling efforts included the following:

- Characterize the hydrogeology of the SFCDR and Canyon Creek Watersheds.
- Develop a quantitative representation of stratigraphy and aquifer properties throughout the SFCDR and Canyon Creek Watersheds.
- Quantify the distribution and extent of groundwater-surface water interaction.
- Develop water budgets for selected areas of the SFCDR and Canyon Creek Watersheds.
- Develop dissolved metals loading budgets for selected areas of concern within the SFCDR and Canyon Creek Watersheds.

Development of the Canyon Creek Watershed groundwater flow model (hereafter referred to as the Canyon Creek Model) began in 2006 as part of the Canyon Creek Hydrologic Study (CH2M HILL, 2007). The purpose of this study was to better understand the hydrologic system within the Canyon Creek Watershed, as Canyon Creek represents one of the largest point discharges of dissolved metals contamination to the greater Coeur d'Alene River system. The Canyon Creek Model was developed using MicroFEM©, an integrated groundwater modeling software program (Hemker and Nijsten, 2003). The finite-element grid consists of 42,086 surface nodes and 83,785 elements in each of the five model layers (Figure A-1). (The figures referenced in the text of this appendix are provided following Section A.9) Nodal spacing was varied from as little as 2 feet near groundwater monitoring well clusters and 20 feet in the Woodland Park area to as much as approximately 850 feet near the model boundary. The lateral extent of the model grid represents the approximate extent of the Canyon Creek Watershed, roughly 22 square miles, as defined by the topographic divide (the ridgeline). The five model layers were discretized to simulate aquifer systems in the alluvium, the weathered bedrock horizon, and the bedrock system. Full documentation of the Canyon Creek Model development is presented in the *Canyon Creek Hydrologic Study Report* (CH2M HILL, 2007).

The grid for the SFCDR Watershed groundwater flow model (hereafter referred to as the SFCDR Model) consists of 134,535 surface nodes and 268,631 elements in each of the seven model layers (Figure A-2). Nodal spacing was refined to as little as 25 feet in areas where analysis of remedial actions was anticipated. The lateral extent of the model grid represents the approximate extent of the SFCDR Watershed, roughly 300 square miles, as defined by the topographic divide (the ridgeline). The seven model layers were discretized to simulate the alluvial aquifer systems of the SFCDR and major tributary valleys, the weathered bedrock horizon, and the underlying bedrock system. Full groundwater flow model documentation is presented in *South Fork of the Coeur d'Alene River Watershed: Basinwide Groundwater Flow Model Documentation* (CH2M HILL, 2009b).

The purpose of this appendix is to document updates to the SFCDR Model that have taken place since the documentation was published (no updates have been made to the Canyon Creek Model), and to describe the application of the two groundwater flow models to the evaluation of remedial alternatives for OUs 2 and 3 that are developed and described in this Focused Feasibility Study (FFS) Report for the Upper Basin of the Coeur d'Alene River. The remedial actions evaluated by the groundwater flow models and documented in this appendix constitute all substantive groundwater actions evaluated in the FFS. There are three main alluvial areas in the Upper Basin for which groundwater actions are evaluated: (1) the Mainstem SFCDR Watershed, Segment 01, which includes the alluvial floodplain of the SFCDR between Wallace and Elizabeth Park; (2) the Woodland Park area of Canyon Creek; and (3) the segment of the SFCDR that passes through OU 2 between Elizabeth Park and Pinehurst.

A.2 Model Updates

The calibrated SFCDR Model, as documented in *South Fork of the Coeur d'Alene River Watershed: Basinwide Groundwater Flow Model Documentation* (CH2M HILL, 2009b), was refined to improve both the characterization of the groundwater-surface water interaction within Government Gulch and the overall calibration of the model in general.

Table A-1 presents measured baseflow surface water and groundwater elevations and stream discharges from locations within Government Gulch. (The tables referenced in this appendix are provided after the figures that follow Section A.9.) Although the data obtained during both the fall 2007 and fall 2008 measurement events are variable from point to point, there was an overall gain in surface water flow within Government Gulch (between staff gauging stations BH-GG-0002 and BH-GG-0001). The calibrated model (CH2M HILL, 2009b) simulated Government Creek as a losing stream throughout the "gulch" portion. To better evaluate remedial actions within Government Gulch, the following updates were made to the SFCDR Model:

- The horizontal hydraulic conductivity in model layers 1 and 2 was adjusted from 60 to 20 and 5 feet per day (feet/day), respectively.

- The thickness of model layer 3 was decreased near the mouth of Government Gulch so that the total aquifer thickness near monitoring well pairs BH-GG-GW-0005/ BH-GG-GW-0006 and BH-GG-GW-0007/BH-GG-GW-0008 more closely matched measured data.
- The horizontal hydraulic conductivity of model layer 3 in the confining unit "window" at the mouth of Government Gulch was decreased from 28.35 to 2.835 feet/day.
- The deep percolation of precipitation within Government Gulch was doubled.

These modifications to the model resulted in improved calibration within the Government Gulch drainage area. The measured stream discharge, as defined by the difference in fall 2008 stream discharge between stream gauging stations BH-GG-0001 and BH-GG-0002 (Table A-1), increased by 0.27 cubic foot per second (cfs) in fall 2008. The revised model simulation predicts that 0.24 cfs of groundwater discharge to Government Creek occurs over that same reach. In comparison, the previous version of the SFCDR Model (CH2M HILL, 2009b) simulated this portion of Government Creek as a losing stream.

As part of the updated baseflow calibration, the SFCDR Model underwent an auto-calibration process using PEST, a nonlinear parameter estimation software package (Dougherty, 2004 and 2007). PEST adjusts user-defined model parameters (e.g., hydraulic conductivity and recharge) to minimize the sum of squared differences between calibration targets and simulated values (e.g., groundwater elevations and groundwater discharge to streams). PEST runs a model for each adjustable parameter in which the value of that parameter is slightly increased or decreased. PEST then identifies how each parameter change affected each calibration target. These changes are combined in a multidimensional system of equations that solves for a new set of parameter values that better match the calibration targets. This is repeated until no further improvement is gained. In the course of a typical calibration exercise with PEST, thousands to tens of thousands of model runs are completed. PEST uses a process of parameter modification and calibration target-matching that is similar to the manual interactive technique used by a groundwater modeler, but PEST has the advantage of being able to perform and analyze tens (or even hundreds) of model runs over a short time period. Although PEST cannot exercise professional judgment on its own, it can be guided by a professional who is familiar with the site and the software.

Targets used in the PEST process included the following:

- Groundwater elevations measured during fall 2008
- Vertical head differences measured during fall 2008
- Groundwater discharge to the SFCDR within the Bunker Hill "Box" (the Box) and Osburn Flats as measured during the 2008 groundwater-surface water interaction studies (CH2M HILL, 2009a and 2009c)
- The total baseflow groundwater discharge to the SFCDR, as measured at the U.S. Geological Survey (USGS) stream gauge at Pinehurst

- The total dissolved zinc load from groundwater to the SFCDR within the eastern gaining stream reach along the northern side of the Central Impoundment Area (CIA)
- The total dissolved zinc load from groundwater to Government Creek within the "gulch" portion

During the auto-calibration process, PEST was able to adjust the horizontal and vertical hydraulic conductivity of model layers 1 though 4 and the streambed conductance parameters for reaches of the SFCDR in the Box and Osburn Flats. Additionally, because the PEST process involved numerous model runs, model layer 7 was deleted in order to decrease the number of nodes in the SFCDR Model and improve simulation run-times. Table A-2 lists the multiplier factors for these parameters retained in the final calibration. Figure A-3 presents the updated alluvial transmissivity distribution for the upper aquifer in the Box, while Figure A-4 presents the updated total alluvial aquifer transmissivity for Osburn Flats. Results of the auto-calibration process are discussed in Section A.3.

No updates or modifications were made to the Canyon Creek Model.

A.3 Additional Model Calibrations

During development of the remedial alternatives to be evaluated in the FFS, it was recognized that it would be advantageous to evaluate the effectiveness of potential actions under a variety of hydrologic conditions, not solely the baseflow conditions that were assumed for the initial calibrations. To accommodate these additional analyses, both the SFCDR and Canyon Creek Models were calibrated to four hydrologic conditions:

- Steady-state calibration to fall baseflow conditions
- Steady-state calibration to critical low-flow conditions, 7Q10
- Steady-state calibration to higher flow conditions, 90th percentile flow
- Transient calibration to an annual hydrologic condition (July 1, 2008 through June 30, 2009)

These additional model calibrations are discussed in Sections A.3.1 through A.3.4, respectively.

A.3.1 Steady-State Baseflow Calibration

The fall 2008 flow conditions that correspond to the baseflow calibration represent an approximately 25th percentile flow condition, as defined by the USGS period of recorded streamflow at the USGS stream gauge at Pinehurst (SF-271). Targets used in the 2008 baseflow calibration included the following:

- Groundwater elevations measured in the fall of 2008
- Vertical head differences measured in the fall of 2008
- Groundwater discharge to the SFCDR within the Box and Osburn Flats, as measured during the 2008 groundwater-surface water interaction studies (CH2M HILL, 2009a and 2009c)

Figure A-5 presents an updated "scattergram" of simulated versus measured groundwater elevations. Figures A-6a, A-6b, and A-6c present residuals between measured and simulated groundwater elevations for the Box and Osburn Flats in map view. Tables A-3 and A-4 present the measured and simulated vertical hydraulic gradients for the Box and Osburn Flats, respectively. Table A-5 presents the measured and simulated groundwater discharge to the SFCDR in the Box and Osburn Flats.

A.3.2 Steady-State 7Q10 Calibration

To evaluate the effectiveness of potential groundwater remedial actions under critical low-flow conditions, the Canyon Creek and SFCDR Models were calibrated to a steady-state 7Q10 flow condition. "7Q10" is defined as the lowest 7-day average daily flow that occurs with a 10-year return period. For the SFCDR at the USGS Pinehurst gauge, the 7Q10 flow has been estimated at 68 cfs (USEPA, 1999). The most recent 7Q10 at this location was recorded in mid-September 2001. Data used as targets for the 7Q10 calibration included groundwater elevations measured in monitoring wells and measured discharge of the SFCDR at Pinehurst. It was assumed that under extreme low-flow conditions, all surface water flow was supplied by groundwater discharge.

To calibrate the SFCDR Model to the 7Q10 flow at Pinehurst, several modifications were made to the boundary conditions to reflect the drier hydrologic conditions. It was assumed that all smaller streams within the model domain were dry during the 7Q10 flow condition. These smaller streams (i.e., all streams except the SFCDR, Canyon Creek, Ninemile Creek, Pine Creek, Government Creek, Milo Creek, Montgomery Creek, Big Creek, Terror Gulch, Twomile Creek, and Placer Creek) were converted from the two-way head-dependent boundary condition to a one-way head-dependent boundary condition. As the result of this conversion, these streams could function as a sink for groundwater, but not a source. The East and West Page Swamps were also converted to one-way head-dependent boundary conditions.

The next change was to lower the stream stage elevations consistent with those measured during fall 2001. The differences in gauge height between mid-September 2001 and fall 2008 (the baseflow calibration period) at the USGS gauges on the SFCDR at Pinehurst and Elizabeth Park, on Canyon Creek at the mouth, on Ninemile Creek at the mouth, and on Pine Creek below Amy Gulch were estimated. Of these gauge locations, those along the tributary streams showed larger gauge heights during the 7Q10 flow condition than during the fall 2008 flow period. As a result, the baseflow stream elevations were used for the tributaries. The difference in gauge height between mid-September 2001 and fall 2008 on the SFCDR was approximately 0.25 foot at Elizabeth Park and 0.50 foot at Pinehurst. The calibrated baseflow stream stage elevation of the SFCDR was decreased by 0.50 foot between the western model boundary and Pinehurst and by 0.25 foot from Pinehurst to the SFCDR headwaters.

The final modification to the SFCDR Model was to adjust the deep percolation of precipitation to reflect the drier hydrologic conditions. This was accomplished by an iterative process of applying a multiplier to the deep percolation distribution, running the model to steady-state solution, and then comparing evaluating the calibration against measured groundwater elevations (at 28 monitoring wells in the Box) and the total ground-water discharge to streams at the western model boundary. The final multiplier used in the

7Q10 simulations was 0.37 (i.e., the final deep percolation values were 37 percent of the baseflow values). Figure A-7 presents a scattergram of simulated versus measured groundwater elevations, while Figures A-8a and A-8b present the distribution of residuals between simulated and measured groundwater elevations in map view. The simulated total groundwater discharge to surface water in the calibrated 7Q10 SFCDR Model was approximately 67 cfs.

Similar changes were made to calibrate the Canyon Creek Model to 7Q10 conditions. The calibrated baseflow stage of Canyon Creek was decreased by 0.25 foot because of the measured gauge height differences between fall 2001 and fall 2006 (the baseflow calibration period for the Canyon Creek Model). The multiplier on the distribution of deep percolation of precipitation from the calibrated 7Q10 version of the SFCDR Model (0.37) was applied to the Canyon Creek Model. No measured groundwater elevations were available in the Canyon Creek Watershed for the 7Q10 calibration period; therefore, the only calibration target used was the total groundwater discharge to surface water during fall 2001 (measured at approximately 11 cfs and simulated at approximately 10 cfs).

A.3.3 Steady-State 90th Percentile Flow Tier Calibration

To evaluate the effectiveness of potential groundwater remedial actions under higher flow conditions, the Canyon Creek and SFCDR Models were calibrated to a steady-state 90th percentile flow condition. The 90th percentile flow at the USGS stream gauge at Pinehurst (SF-271) has been estimated at 1,290 cfs (USEPA, 1999). The most recently available data that were obtained during the spring runoff period of Water Year 2009 were used during the calibration. The first occurrence of a 1,290 cfs flow on the rising limb of the SFCDR spring runoff hydrograph occurred on April 20, 2009. Calibration targets for the 90th percentile flow simulations included groundwater elevations measured by transducers in monitoring wells and piezometers on April 20, 2009. As groundwater discharge to streams is not the sole component of streamflow during spring runoff, it was not possible to calculate the quantity of groundwater discharge contributing to surface flow, and therefore no flow targets were used in these calibration simulations.

To calibrate the SFCDR Model to the 90th percentile flow at Pinehurst, modifications were made to boundary conditions to reflect the wetter hydrologic conditions. The stream stage elevations for all streams in the model were modified to be consistent with measured data. For all streams where data-logging pressure transducers were installed, the difference between the stage during fall 2008 and the stage on April 20, 2009, was estimated. This difference was then added to or subtracted from the stream stage in the calibrated baseflow model. Although many stilling wells on tributary streams are instrumented with transducers, it was necessary to work in stage differences because reference point elevations are not available for the stream gauges on the SFCDR. Table A-6 lists the stage changes implemented for all streams in the SFCDR Model. Where there was more than one stream gauge on a particular stream, the water-level change was applied to reaches defined by the half-distance between gauge locations (i.e., there was no interpolation of stream stage change between gauges). Larger, non-instrumented streams were assigned stream stage changes observed at the mouth of Government Gulch, while smaller streams were assigned stage changes consistent with that observed at the mouth of Deadwood Gulch.

Modification of the deep percolation of precipitation to reflect the wetter hydrologic conditions was accomplished in a similar manner to that used in the 7Q10 calibration. A multiplier was applied to the baseflow deep percolation distribution, the model was run to steady-state solution, and the simulated groundwater elevations were compared to the measured values at 73 monitoring wells and piezometers in the Box and Osburn Flats. This process was repeated until a reasonable calibration was achieved. The final multiplier used in the 90th percentile flow simulations was 3 (i.e., the final deep percolation values were three times greater than the baseflow values). Figure A-9 presents a scattergram of simulated versus measured groundwater elevations, while Figures A-10a, A-10b, and A-10c present the distribution of residuals between simulated and measured groundwater elevations in map view.

Calibration of the Canyon Creek Model to the 90th percentile flow condition involved modifications to boundary conditions similar to those previously discussed. The stream stage elevations were modified based on data recorded at stilling wells A2-SSD, A4E-SSD, and A6-SSD and the USGS stream gauge CC-288. Because the three stilling wells have surveyed reference point elevations, actual stream stage values measured on April 20, 2009, were incorporated into the calibration of the Canyon Creek Model, as opposed to the gauge height differences used in the SFCDR Model calibration. A stream stage value for stream gauge CC-288 was calculated using the gauge height difference between April 20, 2009, and the fall of 2006. New stream stage elevations were then applied to all stream nodes in the model by interpolating stream stage values, as a function of distance, between the four stilling well/gauge locations. From stilling well A2-SSD to the Canyon Creek headwaters, the baseflow stream stage elevation was decreased by 0.055 feet, the difference between the baseflow and 90th percentile stream stages at this stilling well. A multiplier was applied to the calibrated baseflow distribution of deep percolation of precipitation in order to simulate the wetter hydrologic conditions. The final multiplier used in the 90th percentile flow simulations was 5.45 (i.e., the final deep percolation values were 5.45 times greater than the baseflow values). Figure A-11 presents a scattergram of simulated versus measured groundwater elevations, and Figure A-12 presents the distribution of residuals between simulated and measured groundwater elevations in map view.

A.3.4 Transient Annual Calibration

The primary methodology used to evaluate the potential benefit of various remedial actions on downgradient surface water quality for this FFS was the Predictive Analysis Tool, discussed in Appendix B of the FFS Report. Because the inputs and outputs to and from this tool are average annual data, it was necessary to calibrate both the SFCDR and Canyon Creek Models to a transient annual condition. It was determined that using the most recent data would provide the largest dataset for these calibrations. At the time of the calibration, the fall 2009 transducer download had not occurred; therefore, it was not possible to calibrate to Water Year 2009. Both groundwater flow models were calibrated to the most recently available data, from July 1, 2008 through June 30, 2009. The output from these model simulations represent the average flows for the 365-day annual period, so they do not represent a long-term average or “typical” conditions.

A.3.4.1 SFCDR Model

Similar to the steady-state calibrations previously listed, modifications to the head-dependent boundary conditions were made to reflect varying hydrologic conditions observed over the course of the year. Streams included in the SFCDR Model are listed in Table A-5. For the stream reaches with stage monitoring equipment and a continuous dataset between July 1, 2008 and June 30, 2009, a new baseline stream state distribution was calculated. This was accomplished by calculating the gauge height difference between July 1, 2008 and September 20 through October 20, 2009 (the baseflow calibration period). This gauge height difference was then applied to the baseflow stream stage distribution for each reach (reaches are defined as the half-distance between the monitoring locations listed in Table A-5). Unmonitored streams were assigned changes in baseflow stream stages consistent with that described for the 90th percentile flow calibration (i.e., small streams were assigned the values from Deadwood Gulch and large streams were assigned the values of the mouth of Government Gulch). For each stilling well and stream gauge location, the average daily deviation from the July 1, 2008 gauge height/stream stage was calculated. These daily deviations were applied to the July 1, 2008 baseline stream stage distribution throughout the transient simulation. Exceptions included the following:

- The Osburn Flats stilling wells were installed in fall 2008; therefore, continuous transducer data for these locations prior to November 2, 2008, were not available. Regressions between available gauge height data at each Osburn Flats stilling wells and data from the Elizabeth Park gauge (SF-268) were developed. These regressions were used to populate the missing gauge height data back to July 1, 2008, for the three Osburn Flats stilling wells. Daily deviations from the July 1, 2008, gauge height were estimated from the entire dataset.

- The new USGS stream gauge at Smelterville Flats (at the western end of the Bunker Hill Box) began recording data on September 23, 2008. A regression was developed between the available gage height data at this gauge and SF-268. This relationship was used to populate the missing gauge height data for the Smelterville Flats gauge. Daily deviations from the July 1, 2008, gauge height were estimated from the entire dataset.

- Where there were gaps in the daily data, the last estimated deviation from the baseline stage prior to the missing data was applied to the entire data gap.

- Transducers in stilling wells BH-BC-0005 and BH-BC-0006 were not submerged over a large portion of the dataset. The estimated deviations from the baseline stream stage distribution for BH-BC-0004 were applied to all Bunker Creek stream reaches.

The second modification that was made to boundary conditions within the SFCDR Model was to vary the quantity of deep percolation of precipitation over the course of the year-long transient simulation. Developing a recharge runoff relationship for the SFCDR Watershed was beyond the scope of this effort; therefore, the deep percolation of precipitation was varied, according to an average unit groundwater hydrograph. Multipliers were applied to the calibrated baseflow distribution of deep percolation of precipitation on a monthly basis. Table A-7 lists the monthly factors. Deep percolation was modified so that the total annual deep percolation within the major alluvial areas equals the average annual deep percolation of precipitation estimated using the Turner approximation (Turner, 1986).

The transient annual simulation was set up such that the model was first run to steady-state under baseflow conditions. At the start of the transient simulation, a specific yield of 6 percent was assigned to alluvial areas of model layers 1 and 2, and a specific storage of 2×10^{-6} x model layer thickness was assigned to bedrock areas of model layers 1 and 2 and all of model layers 3 through 6. The baseline July 1, 2008 stream elevation distribution was loaded, and the July 2008 multiplier was applied to the deep percolation distribution. The transient simulation then proceeded with stream stage varying on daily time steps and deep percolation of precipitation varying on monthly time steps. Targets for the transient average annual simulation consisted of average daily measured groundwater elevations at 69 monitoring wells and piezometers within the Box and Osburn Flats. Simulated heads for each of these locations and simulated groundwater discharge to surface water were output on a daily basis. At the end of each simulation, the calibration to measured groundwater elevations was evaluated and additional modifications were made as necessary. During the calibration process many parameters were varied to test the improvement to the overall calibration, including: varying the streambed resistance terms, modifying the stream stage elevations, varying the vertical resistance terms between model layers, decreasing the specific yield, and globally decreasing the initial heads. Of the parameter variations previously listed, the following modifications were retained in the final transient calibration:

- Reduction of the baseline July 1, 2008 stream stage in the SFCDR reach defined by the Elizabeth Park stream gauge by 1 foot
- Re-interpolation of the baseline July 1, 2008 stream stage distribution of the SFCDR reach between monitoring wells BH-SF-E-101-U and BH-SF-E-0314-U
- Re-interpolation of the baseline July 1, 2008 stream stage distribution of the SFCDR reach between monitoring locations BH-SF-W-PZ-05 and BH-SF-W-0201-U

Because the groundwater hydrographs in monitoring wells and piezometers near the SFCDR showed similar magnitude of responses to the SFCDR hydrograph, it was assumed that the SFCDR was in hydraulic connection with the groundwater system. Although there were no stream gauges in the reaches listed above, groundwater elevations measured on July 1, 2008, at monitoring wells adjacent to the SFCDR were used as data points for the re-interpolation of the baseline stream stage distribution. Plots showing simulated versus measured groundwater elevations from the final transient calibration targets are presented on Figures A-13a through A-13i.

A.3.4.2 Canyon Creek Model

The transient average annual calibration for the Canyon Creek Model followed a similar methodology as described for the SFCDR Model. Rather than establishing a baseline stream stage for the July 1, 2008 initial condition and then applying changes in stream stage from this distribution based on gauge height deviations, average daily stream stage distributions were developed. Daily stream stage distributions were based on linear interpolation, as a function of distance between gauges, of pressure transducer data recorded at stilling wells A2-SSD, A4E-SSD, and A6-SSD and the USGS stream gauge at the mouth of Canyon Creek (CC-288). Because no reference point elevation was available for the USGS stream gauge at the mouth of Canyon Creek, it was necessary to estimate an initial stream stage for interpolation based on the difference in gauge height between July 1, 2008 and the fall 2006 baseflow calibration period. Daily stream stages were calculated based on gauge height deviations from this starting condition. Additionally, it was necessary to develop “soft” data points for nodes representing the headwaters of Canyon Creek and the southwestern model boundary at the confluence with the SFCDR. A constant stream stage of 5,856 feet mean sea level (msl) was used in the daily interpolation of the headwaters node. The node representing the confluence with the SFCDR was assumed to have a stage 3 feet lower than that at stream gauge CC-288. Daily stream stages were interpolated between:

- The southwestern model boundary (confluence with the SFCDR) and gauge CC-288
- Gauge CC-288 and stilling well A6-SSD
- Stilling wells A6-SSD and A4E-SSD
- Stilling wells A4E-SSD and A2-SSD
- Stilling well A2-SSD and the headwaters of Canyon Creek

An annual average deep percolation of precipitation distribution (based on the Turner approximation [Turner, 1986]) was developed for the Canyon Creek Watershed. The annual distribution was apportioned monthly, by applying multipliers to the distribution based on the approximate trend of an average annual groundwater hydrograph. This approach differed from the approach used in the SFCDR Model calibration; the multipliers were applied to an average annual distribution rather than the calibrated baseflow distribution of deep percolation of precipitation. Table A-8 provides the values of the monthly multipliers applied to the deep percolation of precipitation distribution. Multipliers were calculated such that the total deep percolation applied during the average annual simulation was consistent with that estimated using the Turner approximation (Turner, 1986).

The model simulation consisted of loading an initial set of heads (the calibrated baseflow heads), assigning the storage values, and applying the changes to the boundary conditions discussed above. A specific yield of 5 percent was assigned to model layer 1, and a specific storage of 2×10^{-6} x model layer thickness was assigned to model layers 2 through 5. The transient simulation was calculated with stream stage varying on daily time steps and deep percolation of precipitation varying on monthly time steps. Targets for the transient average annual simulation consisted of average daily measured groundwater elevations at eight monitoring wells within the Woodland Park area of the Canyon Creek Watershed. Simulated heads for each of these locations and simulated groundwater discharge to surface water were output on a daily basis. The match between simulated and measured groundwater elevations from the initial transient simulation was acceptable; therefore, no model parameters were changed. Plots showing simulated versus measured groundwater elevations from the final transient calibration are presented on Figure A-14.

A.4 Methodology for Development of Metals Loading Budget

The calibrated groundwater flow models provide improved estimates of the magnitude of groundwater-surface water interaction within the Box, Osburn Flats, and the Canyon Creek Watershed. This information was used to identify the location and magnitude of groundwater discharge to streams within the watershed. By combining the groundwater discharge estimates with dissolved metals concentrations in groundwater, the groundwater flow data can be converted into estimates of metals flux from groundwater to surface water.

The SFCDR and Canyon Creek Models are groundwater flow models; therefore, metals transport and geochemical reactions are not simulated. As an alternative, dissolved metals loadings to the surface water were estimated by dividing the gaining portions of the SFCDR and Canyon Creek into reaches, and selecting representative monitoring wells that are assumed to reflect the dissolved metals concentrations in groundwater entering the stream over a given reach. The average dissolved metals concentrations within a particular reach can then be multiplied by the simulated groundwater flow to the stream reach predicted by the groundwater flow model to yield estimates of metals loadings. These values can then be compared with more traditional loading calculations, derived from comparing calculated upstream and downstream loads based on surface water flows and surface water metals concentrations, to evaluate consistency in the independent loading estimates. If the estimates agree reasonably well, confidence is gained that the independent predictions of metals loadings to the stream over certain reaches are reasonably accurate. This methodology assumes that (a) dissolved zinc can be used as a surrogate for other metals (i.e., the reaches with the greatest zinc loads are also areas with the highest cadmium loads), and (b) there is no change in dissolved metals concentrations in groundwater between the location of the groundwater monitoring well and the discharge area into the stream (i.e., metals transport in the groundwater system is conservative between the monitoring well and the stream discharge area). The most recent dissolved zinc concentration data (collected in fall 2008) were used in this analysis.

A.4.1 Baseline Metals Loadings—SFCDR Model

Dissolved zinc loadings to the SFCDR were estimated by combining the simulated groundwater discharge rates to the stream with the dissolved zinc concentrations measured in nearby groundwater monitoring wells. Figure A-15 presents the distribution of dissolved zinc in the groundwater system measured during the fall 2008 and spring 2009 sampling events in the Bunker Hill Box. To estimate the metals loadings from groundwater discharge within the Box, the SFCDR and major tributaries were subdivided into 29 reaches. The streams were subdivided so that there was one monitoring well or piezometer associated with each reach. The geographic locations of these reaches are shown on Figure A-15. For a given simulation, the simulated groundwater discharge to the stream was multiplied by the dissolved zinc concentration in groundwater measured at the associated monitoring well or piezometer, and the simulated flow from the stream to the groundwater system was multiplied by the dissolved zinc concentration in surface water measured during the 2008 OU 2 groundwater-surface water interaction study (CH2M HILL, 2009a). The net dissolved zinc load for each reach was calculated as the difference between the stream load gained and lost. The calculated net loads for all 29 reaches were then added together to estimate a total load gained through the Box under a particular hydrologic condition. Dissolved zinc concentrations for the hydrologic conditions described in Section A.3.4 were used as follows:

- Baseflow—fall 2008 dissolved zinc concentration
- 7Q10—fall 2008 dissolved zinc concentration
- 90th percentile flow—spring 2009 dissolved zinc concentration

- Transient annual—fall 2008 dissolved zinc concentrations were applied to the time frame from August 1, 2008 through March 15, 2009; spring 2009 dissolved zinc concentrations were applied to the time frames from July 1, 2008 through July 31, 2008 and from March 16, 2009 through June 30, 2009.

Dissolved zinc loading for the remedial action simulations followed a similar methodology as discussed above to estimate total loading to the surface water system. Estimates of dissolved zinc loading to groundwater collection systems were calculating by multiplying the simulated load to the French drains included in the remedial alternatives for OU 2 by the average groundwater concentration in adjacent monitoring wells and piezometers. It was assumed that the French drain systems simulated in the OU 2 alternatives were set far enough away from streams that any induced flow from streams would flow through contaminated sediments before discharging to the drain systems.

For groundwater actions proposed for the Mainstem SFCDR Watershed, Segment 01, the dissolved zinc load was calculated as previously described. For all hydrologic conditions, the dissolved zinc concentration was assumed to be equal to the average concentration measured in Osburn Flats monitoring wells in fall 2008 (1.8 milligram per liter [mg/L]), and the surface water concentration was assumed to be the average measured during the 2008 Osburn Flats groundwater-surface water interaction study (0.75 mg/L) (CH2M HILL, 2009c).

Discussions of how each of the above remedial alternatives was simulated and the results are provided in Sections A.5 and A.6.

A.4.2 Baseline Metals Loadings—Canyon Creek Model

The zinc loading to Canyon Creek was estimated using a similar methodology as described above for the SFCDR Model. The model-simulated groundwater discharge rates were multiplied by the observed zinc concentrations measured in monitoring wells in the Woodland Park area of the Canyon Creek Watershed. The dissolved zinc loading estimates focused on this area of the watershed because this is where groundwater components of various remedial actions were evaluated. To estimate the metals loading from groundwater discharge, the Woodland Park area was subdivided into 12 reaches. The geographic location of each reach and the distribution of dissolved zinc in groundwater, as measured during fall 2006, are shown on Figure A-16. For the purposes of this FFS, the average dissolved zinc concentration within each reach was calculated; these data are provided in Table A-9. Dissolved zinc loading to the surface water system was estimated by multiplying the simulated total groundwater discharge to Canyon Creek and to land surface by the average dissolved zinc concentration within each reach. This methodology assumes that ground-water discharge to low-lying areas adjacent to Canyon Creek eventually flows into the stream. The total dissolved zinc load to Canyon Creek through Woodland Park was estimated as the sum of all 12 reaches. Because the fall 2006 sampling event represents the most recent synoptic dissolved zinc dataset for the Canyon Creek Watershed, these data were used for estimating dissolved zinc loading under all hydrologic conditions described Section A.3.

Remedial actions proposed for the Woodland Park area include various source control and sediment removal actions. It was assumed that these actions would reduce the dissolved zinc concentrations in groundwater. The magnitude of these reductions within each of the 12 Woodland Park reaches was assumed to be a function of the percent of material removed, the remedial effectiveness factor (REF) from the Simplified Tool for Predictive Analysis[1], and the fraction of the total area of each reach represented by a given source. The estimation of the reduction in dissolved zinc concentrations in groundwater resulting from source removal actions was as follows:

- The percentage of total volume of each contaminant source proposed to be removed was estimated (Table A-10, column 3).
- The REF for each type of source removal action was taken from the Simplified Tool (Table A-10, column 4).
- The effective REF for each type of source removal action was calculated by multiplying the proposed percentage of material to be removed by the REF (Table A-10, column 5).
- For each Woodland Park reach, the area of contaminant source within the reach was estimated (Table A-10, column 6).
- For each Woodland Park reach, the fraction of the total area represented by each contaminant source was calculated (Table A-10, column 7).
- For each Woodland Park reach, the fraction of the total area for each contaminant source was multiplied by effective REF (Table A-10, column 8).
- The total REF for each reach was the sum of all the fractions of effective REFs for all contaminant sources within the reach (Table A-10, column 9).

The total REFs for the reaches were used to reduce the average dissolved zinc concentration in groundwater by assuming that for a given reach, the concentration would be reduced by a percentage equal to the total REF. For example, for Reach 01, the total REF for the reach was estimated to be 69 percent; this means that the average dissolved zinc concentration after the source removal actions are completed would be 31 percent of the initial concentrations. The pre-removal action and estimated post-source-removal-action dissolved zinc concentrations in groundwater are presented in Table A-9. A complete discussion of the simulation results is presented in Section A.6.

A.5 Application of Groundwater Flow Models to Remedial Alternatives for OUs 2 and 3

This section describes how the groundwater components of each of the remedial actions included in the applicable remedial alternatives described in Sections 6.0 and 7.0 of the FFS Report were implemented in the SFCDR and Canyon Creek Models. These components were consistently implemented in the models for all steady-state and transient hydrologic

[1]The Simplified Tool was developed in 2008 to provide a simplified version of the Predictive Analysis that was used in the Remedial Investigation/Feasibility Study for the Coeur d'Alene Basin (USEPA, 2001a, 2001b, and 2007) and is also used in this FFS Report. The Simplified Tool allows for the evaluation of source sites and the potential benefits of specific remedial actions for smaller segments of a stream, as opposed to the aggregated source sites and remedial actions evaluated using the Predictive Analysis. The *Working Draft Technical Memorandum: Overview of the Simplified Predictive Analysis for Estimating Post-Remediation Water Quality* (CH2M HILL, 2008) presents the details of how the Simplified Tool was developed.

flow conditions discussed in Section A.3. The results of the simulations are presented in Section A.6.

A.5.1 OU 2 Alternative (a)

OU 2 Alternative (a) consists of limited stream-lining actions in losing reaches of OU 2 streams to reduce recharge to the shallow alluvial groundwater system. The overall goal of this alternative is to reduce the mobilization, transport, and mass flux of dissolved metals in the groundwater system by reducing stream leakage from losing portions of the SFCDR and tributaries, which would ultimately protect surface water downstream. This alternative was developed to provide a limited passive action alternative without water treatment. The locations of stream liners included in this alternative are based on the low operation and maintenance (O&M) and minimal water management option identified during the OU 2 remedial alternative screening process, and were optimized during this process. Figure A-17 shows the locations of the stream liners that comprise this alternative, which include the following:

- Lining the SFCDR from the eastern portion of the Box to the I-90 underpass at the northeast corner of the CIA
- Lining Bunker Creek from the Central Treatment Plant (CTP) to the I-90 culvert
- Lining Magnet Gulch from McKinley Avenue to the confluence with Bunker Creek
- Lining Deadwood Gulch from McKinley Avenue to the confluence with Bunker Creek

For all the steady-state and transient simulations discussed in Section A.3, these stream liners were simulated in the SFCDR Model by assigning a streambed conductance term of zero where liners will be installed. This effectively removes the boundary condition from these nodes, eliminating groundwater and surface water exchange.

A.5.2 OU 2 Alternative (b)

OU 2 Alternative (b) consists of extensive stream lining actions in OU 2 streams to reduce recharge to the shallow alluvial groundwater system. Groundwater cutoff walls would be installed at select locations as part of this alternative. The overall goal of OU 2 Alternative (b) is to (more extensively than OU 2 Alternative (a)) reduce the mobilization, transport, and mass flux of dissolved metals in the groundwater system to the extent practicable, with no groundwater treatment, by reducing stream leakage from losing portions of tributaries to the SFCDR, which would ultimately protect surface water downstream. To achieve this goal, losing stream reaches were selected for lining. Similar to OU 2 Alternative (a), the locations of stream liners included in this alternative are based on the objective of low O&M and minimal water management as identified during the OU 2 remedial alternative screening process, and were optimized during this process. Figure A-18 shows the locations of the components of this alternative, which include the following:

- Lining Bunker Creek from the CTP to the confluence with Bunker Creek
- Lining Magnet Gulch from the point in the SFCDR Watershed where surface water has elevated metals concentrations (approximately half the distance to the headwaters) to the confluence with Bunker Creek

- Lining Deadwood Gulch from where surface water has elevated metals concentrations (approximately half the distance to the headwaters) to the confluence with Bunker Creek
- Lining Government Creek from the upstream point of Government Gulch to the confluence with Bunker Creek
- Installing groundwater cut-off walls at the upstream end of all stream liner segments except those on Bunker Creek
- Installing clean groundwater collection sumps on the upstream side of the groundwater cut-off walls
- Installing sub-liner collection systems below stream liners, except those on Bunker Creek, to prevent floating the liners in gaining stream reaches

For the steady-state and transient simulations discussed in Section A.3, stream liners were simulated in the SFCDR Model by assigning a streambed conductance term of zero where liners will be installed. This effectively removes the boundary condition from these nodes, eliminating groundwater and surface water exchange. Groundwater cut-off walls were simulated by assigning anisotropy to the horizontal hydraulic conductivity field. Anisotropy was assigned to alluvial layers in the location of cut-off walls such that the hydraulic conductivity in the direction of groundwater flow was 1 percent of the hydraulic conductivity perpendicular to flow. For example, the horizontal hydraulic conductivity in the alluvial valley of Deadwood Gulch is 10 feet/day. In the location of the groundwater cut-off wall, the hydraulic conductivity in the downgradient flow direction is 0.1 foot/day, while the hydraulic conductivity perpendicular to flow remains at 10 feet/day. This methodology allowed the assignment of a barrier to flow without having extremely large contrasts in model properties in adjacent nodes, thereby increasing the numerical stability of the model simulation. Groundwater sumps on the upstream side of cut-off walls and sub-liner collection systems were simulated using the MicroFEM drain package. These one-way head-dependent boundary conditions act as sinks when simulated groundwater elevations exceed the drain elevations, but do not act as sources of water when the simulated groundwater elevations are lower than drain elevations. Drain elevations were set at 2.5 feet below the calibrated baseflow groundwater elevation for all steady-state and transient model simulations. This means that during simulations of “wetter” and “drier” hydrologic conditions, the drain elevation did not fluctuate with the simulated water table.

A.5.3 OU 2 Alternative (c)

OU 2 Alternative (c) consists of a French drain system located in the central portion of OU 2 in the area with the highest dissolved metal load gains observed in the SFCDR. This French drain system would intercept dissolved-metals-contaminated groundwater prior to discharging to the SFCDR. Figure A-19 shows the locations of the components of this alternative, which include the following:

- Piping the CTP effluent directly to the SFCDR along the eastern side of the CIA instead of conveying the discharge down Bunker Creek.
- Installing a French drain parallel to the SFCDR in the highest dissolved metals loading reach between the CIA and I-90.

- Installing a French drain perpendicular to the SFCDR alluvial valley in the narrows between the eastern and western portions of the Box. This drain would be keyed in to the bedrock on the western side of the mouth of Government Gulch.

The piping of the CTP discharge directly to the SFCDR was simulated in the SFCDR Model using the same methodology as used for the stream liners discussed in previous sections. A streambed conductance term of zero was assigned to the entire length of Bunker Creek, eliminating groundwater and surface water exchange. The French drains were simulated using the MicroFEM drain package. French drain elevations were set at either the geological contact between the upper aquifer and the confining unit or at 25 feet below ground surface, whichever was shallower. Additionally, drain elevations were assigned such that there was a slope towards the pump station near Bunker Creek. The same drain elevations were used for model simulations under all hydrologic conditions. A hydraulic conductivity of 1,500 feet/day was assigned along the French drains to simulate coarse backfill material.

A.5.4 OU 2 Alternative (d)

OU 2 Alternative (d) consists of French drains, stream linings, cutoff walls, and extraction wells located in the central portion of OU 2, primarily in the area with the highest dissolved metal load gains observed in the SFCDR. Similar to OU 2 Alternatives (a) and (b), the overall goal of stream lining is to reduce the mobilization, transport, and mass flux of dissolved metals in the groundwater system to the extent practicable by reducing stream leakage from Government Creek. This alternative would reduce groundwater recharge and intercept dissolved-metals-contaminated groundwater for treatment prior to discharging to the SFCDR. Figure A-20 shows the locations of the components of this alternative, which include the following:

- Lining Government Creek from the upstream point of Government Gulch to the I-90 culvert
- Installing a groundwater cut-off wall at the upstream end of the stream liner
- Installing clean groundwater collection sumps on the upstream side of the groundwater cut-off wall
- Installing a line of contaminated groundwater collection wells at the mouth of Government Gulch
- Installing sub-liner collection systems below stream liners to prevent the liners from floating where Government Creek is gaining
- Piping the CTP effluent directly to the SFCDR along the eastern side of the CIA instead of conveying the discharge down Bunker Creek
- Installing a French drain parallel to the SFCDR in the highest dissolved metals loading reach between the CIA and I-90
- Installing a French drain perpendicular to the SFCDR alluvial valley in the narrows between the eastern and western portions of the Box. This drain would be keyed in to the bedrock on the eastern side of the mouth of Government Gulch

Stream lining and piping the CTP effluent directly to the SFCDR, rather than conveyance via Bunker Creek, were simulated in the SFCDR Model as discussed above, by assigning a streambed conductance term of zero to affected stream nodes. The groundwater cut-off wall at the head of Government Gulch was simulated, as discussed for OU 2 Alternative (b), by assigning anisotropy to the horizontal hydraulic conductivity field. The groundwater sumps on the upstream side of the cut-off wall, the sub-liner collection system, the French drains in the SFCDR valley, and the line of extraction wells at the mouth of Government Gulch were simulated using the MicroFEM drain package. The drain elevations of the sumps and the sub-liner collection system were set at 2.5 feet below the calibrated baseflow groundwater elevation for all steady-state and transient model simulations. The elevations of the French drains in the SFCDR valley were set at either the geological contact between the upper aquifer and the confining unit or at 25 feet bgs, whichever was shallower. Additionally, drain elevations were assigned so that there was a slope towards the pump station near Bunker Creek. The drain elevation of the line of extraction wells at the mouth of Government Gulch was set at the geological contact between the alluvium and bedrock. The same drain elevations were used for model simulations under all hydrologic conditions. A hydraulic conductivity of 1,500 feet/day was assigned along the French drains and the line of extraction wells to simulate coarse backfill material.

A.5.5 OU 2 Alternative (e)

OU 2 Alternative (e) is the most extensive water collection and management alternative, incorporating extensive stream lining of the SFCDR and its tributaries, as well as French drain systems. The goal of OU 2 Alternative (e) is "no-net gain in dissolved metals through the Bunker Hill Box". Figure A-21 shows the locations of the components of this alternative, which include the following:

- Lining Government Creek from the upstream point of Government Gulch to the confluence with the SFCDR, the SFCDR throughout the Bunker Hill Box, the entire length of Bunker Creek, Deadwood Gulch and Magnet Gulch from where surface water has elevated metals concentrations to the confluence with Bunker Creek, and Humboldt Creek and Grouse Creek from where they enter the SFCDR valley to the confluence with the SFCDR
- Installing groundwater cut-off walls at the upstream end of the stream liners
- Installing a groundwater cut-off wall at the western end of the Box (installed to the top of the confining unit)
- Installing a clean groundwater cut-off wall at the eastern end of the Box (installed to bedrock)
- Installing clean groundwater collection sumps on the upstream sides of the groundwater cut-off walls
- Installing sub-liner collection systems below stream liners to prevent the liners from floating where Government Creek, Magnet Gulch, and Deadwood Gulch are gaining
- Installing a French drain in the eastern portion of the Box (between the CIA and I-90) to prevent the liner from floating where the SFCDR is gaining

- Installing a French drain in the western portion of the Box (in Smelterville Flats) to prevent the liner from floating where the SFCDR is gaining
- Removing the weirs in the Page Swamps

Stream liners were simulated in the SFCDR Model as discussed above, by assigning a streambed conductance term of zero to affected stream nodes. Groundwater cut-off walls were simulated, as discussed for OU 2 Alternative (b), by assigning anisotropy to the horizontal hydraulic conductivity field. The groundwater sumps on the upstream sides of cut-off walls, the sub-liner collection systems, and French drains in the SFCDR valley were simulated using the MicroFEM drain package. The drain elevations of the sumps and sub-liner collection systems were set at 2.5 feet below the calibrated baseflow groundwater elevation for all steady-state and transient model simulations. The elevations of the French drain north of the CIA were set at either the geological contact between the upper aquifer and the confining unit or 25 feet below ground surface, whichever was shallower. Additionally, drain elevations were assigned such that there was a slope towards the pump station near Bunker Creek. The drain elevation of the French drain in Smelterville Flats was set at 5 feet below the calibrated baseflow water table. The same drain elevations were used for model simulations under all hydrologic conditions. A hydraulic conductivity of 1,500 feet/day was assigned along the French drains north of the CIA and in Smelterville Flats to simulate coarse backfill materials. Weir removal was simulated by converting the Page Swamps from a two-way head-dependent boundary condition to a one-way head-dependent boundary condition. Because ponding no longer occurs within the swamps, these could function as sinks for groundwater but not as a source of groundwater recharge.

A.5.6 Groundwater Components of OU 3 Remedial Alternatives for the Mainstem SFCDR Watershed, Segment 01

Figure A-22 shows the groundwater components of all the OU 3 remedial alternatives for the Mainstem SFCDR Watershed Segment 01. The objective of this remedial alternative was to hydraulically isolate this reach of the SFCDR via stream lining and collection and treatment of dissolved-metals-contaminated groundwater that would otherwise discharge to the SFCDR. The components of this alternative include the following:

- Lining the SFCDR from approximately Wallace to Elizabeth Park
- Installing a French drain adjacent to the stream liner to prevent floating the liner in gaining stream reaches
- Capping tailings piles at the Silver Dollar Mine (site KLE034), the Silver Crescent Mine (site KLE011), the Osburn Rock Pit along I-90 (site WAL035), and the Caladay Mine (site WAL020). These actions were included in the model simulations as they reduce groundwater recharge due to deep percolation of precipitation

Lining the SFCDR was simulated in the SFCDR Model, as discussed for the OU 2 alternatives, by assigning a streambed conductance term of zero to lined stream nodes. The French drain along the SFCDR was simulated using the MicroFEM drain package. The drain elevation was set at 5 feet below the calibrated baseflow groundwater elevation for all steady-state and transient model simulations. A hydraulic conductivity of 1,500 feet/day was assigned along the French drain to simulate coarse backfill materials. Capping the tailings piles was simulated by assigning a deep percolation of precipitation of zero to model nodes representing the capped areas.

A.5.7 Groundwater Components of OU 3 Remedial Alternatives for Woodland Park

The updated groundwater components of the actions for the Woodland Park area included in the OU 3 remedial alternatives were simulated using the Canyon Creek Model. These components include a combination of stream liners and French drains that would be installed along Canyon Creek to reduce dissolved metals loading to the creek and to collect metals-contaminated water. The stream liners and French drains would be placed at locations that would maximize dissolved metals load reduction in the creek and minimize cost by (a) intercepting metals-contaminated groundwater that would otherwise discharge to Canyon Creek, and (b) reducing the mobilization, transport, and mass flux of dissolved metals in the groundwater system by reducing stream leakage from losing portions of Canyon Creek. The locations of stream liners and French drains included in this alternative were optimized during the remedial alternative screening process. Figure A-23 shows these components, which include the following:

- Lining the losing reach Canyon Creek from approximately Site A2 to Site A4E
- Installing a French drain adjacent to Canyon Creek from approximately Site A2 to A6
- Installing a French drain cut-off system perpendicular to the Canyon Creek alluvial valley near Site A-6
- Installing a French drain along the base of the Silver Valley Natural Resource Trust tailings repository
- Piping the Gem portal discharge directly to Canyon Creek instead of discharging the effluent to Hecla Star Pond 6

Lining Canyon Creek was simulated, as discussed for the OU 2 alternatives, by assigning a streambed conductance term of zero to lined stream nodes. All of the French drain systems were simulated using the MicroFEM drain package. The drain elevations were set at 5 feet below the calibrated baseflow groundwater elevation for all steady-state and transient model simulations. Piping of the Gem portal discharge was simulated by removing the specified flux for all nodes representing Hecla Star Pond 6.

A.6 Simulation Results

Groundwater components of the remedial alternatives described in the previous section were simulated using the SFCDR and Canyon Creek groundwater flow models. The modeling simulations were performed to obtain an estimate of the relative effectiveness of each of the alternatives at reducing the dissolved metals loading to the SFCDR or Canyon Creek. The effectiveness of each alternative was estimated by running a model simulation with a remedy-in-place, and comparing the results with a baseline no-action simulation. The difference in metal loading between the two simulations was assumed to be the benefit of implementation of that particular alternative. Other information obtained from the model simulations were estimated drain flows and CTP loads for the various remedial alternatives evaluated. The sole metric used in this analysis to quantify alternative effectiveness was the reduction in dissolved metals load to the SFCDR or Canyon Creek. While other benefits, such as minimizing treatment loading or keeping clean water clean, could also be considered, the assessment herein uses metal load reduction as the primary differentiator of remedy effectiveness for the purposes of comparing alternatives.

A.6.1 Baseflow Conditions

Groundwater components of the remedial alternatives were simulated under steady-state baseflow conditions observed during fall 2008 (the SFCDR Model) and fall 2006 (the Canyon Creek Model). This time period represents an approximate 25th percentile flow as defined by the SFCDR flow at the USGS stream gauge at Pinehurst (SF-271). Figure A-24 presents upstream flowlines from gaining portions of the SFCDR under these conditions. This figure also presents the simulated gaining and losing reaches of the SFCDR and tributaries for which stream lining is proposed in the alternatives described above. These flowlines suggest that under no-action baseline conditions, the primary sources of water to gaining portions of the SFCDR in the eastern portion of the Box include the losing reaches of the SFCDR and Bunker Creek, the groundwater underflow from the SFCDR alluvial system upstream of the Box, and underflow from the Milo Creek Watershed. The primary sources of water to the gaining reaches of the SFCDR in the western portion of the Box include the Page Swamps and losing reaches of the SFCDR and Government Creek. (Flowline figures are only presented for the baseflow conditions; flowlines for other hydrologic conditions show similar patterns).

Figure A-25 presents upstream flowlines from the same gaining reaches of the SFCDR with the components of OU 2 Alternative (a) in place. These flowlines are similar to the no-action baseline conditions, except that they do not track back to losing reaches of the SFCDR and Bunker Creek, as these stream reaches would be lined. Rather, a larger portion of the groundwater that discharged to these gaining reaches would originate as groundwater underflow from the SFCDR alluvial system upstream from the Box and underflow from the Milo Creek Watershed.

Figure A-26 presents upstream flowlines from the same gaining reaches of the SFCDR with the components of OU 2 Alternative (b) in place. These flowlines are similar to the no-action and OU 2 Alternative (a) conditions, except that flowlines do not track back to the tributary valleys of Bunker Creek due to the more extensive stream lining and groundwater cut-off walls in these gulches.

Figure A-27a presents upstream flowlines from the same gaining reaches of the SFCDR with the components of OU 2 Alternative (c) in place. This figure shows that a majority of the reach of the SFCDR north of the CIA would no longer be gaining. Flowlines from the portion of this reach that would still be gaining sweep north of the SFCDR under Kellogg. Figure A-27b presents upstream flowlines from the French drain system. This figure illustrates that a majority of the contaminated groundwater flowing beneath the CIA that once discharged to the SFCDR would be captured by the French drains.

Figures A-28a and A-28b present upstream flowlines from the gaining reaches of the SFCDR and the French drain systems with the components of OU 2 Alternative (d) in place. These figures indicate that groundwater flow patterns would be similar to those discussed for OU 2 Alternative (c).

Figure A-29 presents upstream flowlines from French drains with the components of OU 2 Alternative (e) in place. No flowlines from gaining reaches of the SFCDR are presented because all streams would be lined within the Box under this alternative. This figure shows that with such extensive stream lining coupled with a cut-off wall at Elizabeth Park, the majority of water entering the French drains would be from groundwater underflow from the Milo Creek Watershed.

Figures A-30 and A-31 show upstream flowlines from gaining portions of the SFCDR under no-action conditions (Figure A-30), and with the French drain system proposed for Mainstem SFCDR Watershed Segment 01 actions implemented (Figure A-31). These figures show that the sources of water to either the SFCDR or the French drain system would be the same: losing portions of the SFCDR, or tributaries and groundwater underflow from the alluvial system upstream. Under the no-action scenario, this water is discharged to the SFCDR; when the stream was lined, however, the water would be discharged to the French drain system.

Figures A-32 and A-33 present upstream flowlines from gaining portions of Canyon Creek under no-action conditions (Figure A-32), and with the French drain system proposed for the updated remedial components for Woodland Park (Figure A-33). Figure A-32 also presents simulated gaining and losing reaches of Canyon Creek under baseflow conditions. These figures show a similar pattern to the pattern for Mainstem SFCDR Watershed Segment 01. Under no-action conditions, water discharging to gaining reaches of Canyon Creek originates from leakage from losing portions of Canyon Creek, groundwater underflow from upstream portions of the alluvial valley, and groundwater underflow from beneath the Silver Valley Natural Resource Trust (SVNRT) repository. With the remedial actions in place, this water would discharge to the French drain systems instead of to Canyon Creek.

Table A-11 presents summaries of simulated flows for the no-action and remedial alternative simulations under baseflow conditions. Under no-action baseline conditions, the SFCDR Model suggests that the SFCDR gain through the Box is approximately 8 cfs, while the loss is approximately 3 cfs. Model results suggest that the stream-lining-only options would not significantly reduce the gain to the SFCDR. Because the eastern losing reach of the SFCDR would be lined, OU 2 Alternative (a) would reduce the leakage from the SFCDR by approximately 2 cfs. OU 2 Alternative (b) would induce more seepage from the SFCDR than the no-action baseline conditions, likely the result of the lining of Government Creek. OU 2 Alternatives (c) and (d) would both reduce the groundwater discharge to the SFCDR by more than 50 percent; however, the French drains would induce stream leakage doubling the SFCDR leakage. Additionally, both alternatives would have a treatment flow of approximately 8.5 cfs. Under OU 2 Alternative (e), the streams would be lined; therefore, no stream loss or gain is simulated. The simulated treatment flow to the French drain and sub-liner collection systems is approximately 5.5. cfs. Within the Mainstem SFCDR Watershed Segment 01, between Wallace and Elizabeth Park in OU 3, the SFCDR Model suggests that the SFCDR would gain approximately 10 cfs and loses 8 cfs. With the remedial actions in place, there would be no groundwater-surface water interaction along the SFCDR as a result of stream lining, and the French drain inflow would be approximately 7.5 cfs. The results of baseflow simulations from the Canyon Creek Model suggest that under no-action baseline conditions, Canyon Creek gains approximately 2 cfs and loses approximately 1 cfs. With the Woodland Park components of the OU 3 remedial alternatives in place, stream gain would be decreased by 0.5 cfs; however, Canyon Creek stream loss would increase by 0.3 cfs, and there would be an inflow of 1 cfs to the French drains.

Table A-12 presents summaries of the estimated dissolved zinc loading under baseflow conditions for the OU 2 and OU 3 baseflow simulations. These data suggest that under no-action baseline conditions, the total dissolved zinc load to the SFCDR through the Box is approximately 600 pounds per day (lb/day). This value is consistent with historical measurements from baseflow groundwater-surface water interaction studies. The stream-lining-only options would reduce the dissolved zinc load to the SFCDR by approximately 100 lb/day. OU 2 Alternative (a) would be more effective at reducing direct load to the SFCDR and the A-4 drain, while OU 2 Alternative (b) would reduce loading to Government Creek. OU 2 Alternatives (c) and (d) would reduce the direct dissolved zinc loading to the SFCDR by approximately 460 lb/day; however, OU 2 Alternative (d) would be more effective overall because it would reduce dissolved zinc loading to Government Creek. Both of these alternatives would have a treatment load of more than 1,000 lb/day. OU 2 Alternative (e) would be 100 percent effective in reducing dissolved zinc loading to the surface water system and would carry a treatment burden of approximately 550 lb/day. The net dissolved zinc loading to Mainstem SFCDR Watershed Segment 01 in OU 3 would be approximately 65 lb/day. As shown in Table A-12, the remedial actions would remove this zinc load from the system; however, the treatment load would be approximately 75 lb/day. Results from the Canyon Creek Model suggest that under no-action baseline conditions, the total dissolved zinc load to the Woodland Park reach of Canyon Creek is approximately 125 lb/day. The Woodland Park components of the remedial alternatives for OU 3 would reduce this loading by approximately 85 lb/day and have a treatment load of approximately 80 lb/day.

A.6.2 7Q10 Conditions

Tables A-13 and A-14 present the model-simulated flows and dissolved zinc load summaries, respectively, for no-action and remedial alternative simulations from the SFCDR and Canyon Creek Models under critical low-flow, 7Q10, conditions. A comparison of Tables A-11 and A-13 shows that the relative trends in simulated flows would be similar between baseflow and 7Q10 conditions. In general, streams would gain slightly less and lose slightly more under 7Q10 conditions than under baseflow conditions. This would be the result of lower groundwater elevations during drier periods.

Table A-14 shows that the estimated dissolved zinc load to the SFCDR under 7Q10 conditions would be approximately 550 lb/day, 50 lb/day less than under baseflow conditions. The five OU 2 alternatives show similar relative effectiveness under 7Q10 conditions as under baseflow conditions. Table A-14 shows that of the two stream-lining-only options, OU 2 Alternative (a) would be more effective under extreme low-flow conditions, probably because of the inclusion of lining the eastern losing reach of the SFCDR. The lining-only alternatives would be less effective than the actions involving the installation of French drains; however, there would be little or no treatment load. The estimated dissolved zinc load to Mainstem SFCDR Watershed Segment 01 in OU 3 would be approximately

60 lb/day under 7Q10 conditions. This load would be eliminated with the remedial actions in place; however, the estimated dissolved zinc load to the French drain would be 60 lb/day. Table A-14 shows that under 7Q10 conditions, the Woodland Park components of the OU 3 remedial alternatives would reduce the dissolved zinc loading to Canyon Creek by 75 lb/day and carry a treatment burden of approximately 50 lb/day.

A.6.3 90th Percentile Flow Conditions

Tables A-15 and A-16 present the model-simulated flows and dissolved zinc load summaries, respectively, for no-action and remedial alternative simulations from the SFCDR Watershed and Canyon Creek models under 90th percentile flow conditions, as defined at the USGS stream gauge at Pinehurst (SF-271). Simulated flows presented in Table A-15 suggest that for the SFCDR and tributaries within OU 2, the stream gains would be lower and stream losses higher during the higher flow conditions than under baseflow and 7Q10 conditions. This is likely because the stages in the surface water system would increase quicker than the groundwater elevations. The larger differential in elevations between the two systems would result in more stream loss and less stream gain. Simulated groundwater discharge to Canyon Creek is higher under 90th percentile flow than the drier hydrologic conditions. Simulated flows also show that in all cases, the French drain inflows would be higher under the wetter hydrologic conditions than during 7Q10 or baseflow periods.

Table A-16 presents the estimated dissolved zinc load to the surface water system within OU 2 and OU 3 under 90th percentile flow conditions. Under the no-action scenario, the estimated dissolved zinc loading to the SFCDR within the Box is 715 lb/day. Results from the SFCDR Model suggest that the relative effectiveness of the OU 2 alternatives would be similar under the wetter hydrologic conditions as under 7Q10 and baseflow conditions. The stream-lining-only options would reduce dissolved zinc loading by approximately 100 lb/day, while the alternatives including French drains would reduce loading by approximately 550 lb/day. The OU 2 Alternative (e) simulation shows some dissolved zinc loading to the surface water system, as the A-4 drain would be active under the wetter hydrologic conditions. The results for Mainstem SFCDR Watershed Segment 01 in OU 3 are similar to those for the other hydrologic conditions. Table A-16 shows that under 90th percentile flow conditions, the estimated dissolved zinc loading to Canyon Creek would be higher under 90th percentile flow conditions than under baseflow and 7Q10 conditions, approximately 260 lb/day. The Woodland Park components of the OU 3 remedial alternatives would reduce dissolved zinc loading to Canyon Creek by nearly 150 lb/day; however, the treatment load would be approximately 180 lb/day.

A.6.4 Average Annual Conditions

Tables A-17 and A-18 present the model-simulated flows and dissolved zinc load summaries, respectively, for the transient annual simulations for the SFCDR and Canyon Creek Models. A comparison of Tables A-11 and A-17 shows that the simulated flows are very similar under baseflow and the average annual conditions. Consistent with the 90th percentile simulation results, the simulated flows for the SFCDR and tributaries within OU 2 show that the stream gains would be lower and stream losses higher during the average annual conditions than under baseflow conditions. The simulated groundwater discharge to Canyon Creek is slightly higher under average annual than baseflow conditions. Simulated flows also show that in all cases, the French drain inflows would be higher under the average annual hydrologic conditions than during baseflow periods.

Table A-18 presents the estimated dissolved zinc load to the surface water system within OU 2 and OU 3 under average annual flow conditions. A comparison of Tables A-12 and A-18 shows that the estimated dissolved zinc loading to the surface water system would be nearly identical under average annual and baseflow conditions. Although the simulated flows between the baseflow and annual simulations differ, the use of variable concentration distributions to estimate the average annual dissolved zinc loading for the transient simulations yields similar results to the steady-state baseflow simulations. The primary differences between the two hydrologic conditions are that OU 2 Alternative (a) would be slightly more effective than OU 2 Alternative (b), and the treatment loads would be slightly higher under average annual conditions. The results from the average annual simulations were used as input to the Predictive Analysis Tool, as discussed in Appendix B of the FFS Report.

A.7 OU 2 Sensitivity Analysis

Numerical models contain inherent uncertainty. Groundwater models are constructed using available field data and professional judgment to develop an accurate numerical representation of the physical features of a given site of interest, as well as of the physical processes that operate at that site. Additionally, the calibration process allows the modeler to further evaluate and modify the model input parameters in order improve the match between selected calibration targets and model predictions. The larger the number of individual calibration targets, and the greater the variety in the types of calibration targets used (e.g., groundwater elevations, simulated flows, vertical hydraulic gradients, and transient aquifer test data), the higher the degree of confidence is gained that the model is able to provide accurate forecasts of future site conditions. There is, however, error associated with measured field data, and numerical model solutions are non-unique, meaning that there are a large number of parameter configurations that can provide an equal level of calibration. To better quantify the potential range of uncertainty in the estimates of dissolved zinc loading to the SFCDR for the five OU 2 alternatives, an uncertainty analysis was undertaken using the SFCDR Model.

The sensitivity analysis performed on the SFCDR Model involved varying one model parameter at a time, within a specified range, and running numerous simulations to yield independent estimates of zinc loading to the SFCDR. The quality of model calibration was evaluated for each of these sensitivity simulations to ensure that the parameter change made in that run did not result in a model that no longer provides acceptable agreement between simulated and observed calibration targets.

Seven model input parameters were selected for modification during the SFCDR Model sensitivity analysis. Each parameter was increased and decreased by two factors, resulting in 28 model simulations for the no-action alternative and each of the five OU 2 alternatives, resulting in a total of 168 simulations. All of the sensitivity simulations were run using the steady-state, baseflow condition. It was assumed that the other hydrologic conditions would result in similar relative uncertainty. The model input parameters that were evaluated during the sensitivity analysis, along with the range of values tested, are summarized as follows:

- **Horizontal hydraulic conductivity in the alluvial aquifer system—**The horizontal hydraulic conductivity of the alluvium in model layers 1 through 4 was multiplied and divided by factors of 5 and 10.
- **Horizontal hydraulic conductivity in the confining unit—**The horizontal hydraulic conductivity of the confining unit in model layer 3 was multiplied and divided by factors of 10 and 100.
- **Horizontal hydraulic conductivity in the bedrock aquifer system—**The horizontal hydraulic conductivity of the bedrock in model layers 1 through 4 was multiplied and divided by factors of 10 and 100.
- **Distribution of deep percolation of precipitation—**The calibrated baseflow distribution of deep percolation of precipitation was increased and decreased by 25 and 50 percent throughout the model domain.
- **The vertical resistance between model layers—**The vertical resistance terms at the interface between model layers 1 and 2, 2 and 3, and 3 and 4 were increased and decreased by factors of 10 and 100 throughout the model domain.
- **The streambed resistance term—**The streambed conductance term for the SFCDR was increased and decreased by factors of 5 and 10.
- **The wadi elevation term—**The baseflow stream stage distribution of the SFCDR was increased and decreased by 1 and 2 feet.

All of these parameter variations, with the exception of the deep percolation of precipitation, were applied prior to assigning properties for the simulation of the various remedial actions. Table A-19 summarizes the estimated dissolved zinc loading to the SFCDR within the Bunker Hill Box for all of the sensitivity analysis simulations. These data are presented graphically on Figure A-34. The baseflow estimates of residual dissolved zinc loading to the SFCDR from the calibrated model are shown as yellow triangles, while the black “x” symbols represent the results of all of the individual sensitivity analysis simulations. These data show that the simulations of the no-action and liner-only alternatives yielded a wider range of dissolved zinc loading estimates than did the simulations of the other alternatives. For example, the alternatives involving French drains show much less overall deviation from the baseflow dissolved zinc loading estimate obtained from the calibrated model, while the simulations of OU 2 Alternative (e) show even less.

In all cases, the highest estimates of dissolved zinc loading to the SFCDR for each alternative are from the simulations with increased horizontal hydraulic conductivity of the alluvial aquifer system. Increases in the hydraulic conductivity by factors of 5 and 10 over the currently assumed values result in extremely high values (up to 10,000 feet/day), greater than would be expected for the aquifer materials present at the site. Therefore, these results are not considered representative of site conditions. The lowest estimated values of dissolved zinc load for each alternative result from a variety of parameter modifications depending on the alternative being evaluated. But all of the parameter changes that resulted in these low estimates involve parameters that make it more difficult for groundwater to discharge upward to the surface water system. These include increases in vertical resistance between layers (reducing vertical flow), increasing the streambed conductance terms, and increasing stream stage.

Overall, these results suggest that given the uncertainty in the model input parameters, it is not possible to predict whether OU 2 Alternative (a) or (b) would be more effective at reducing metals loading to the SFCDR. However, these results also clearly indicate that OU 2 Alternatives (c) and (d) would be more effective than the liner-only alternatives, and it appears that Alternative (d) would be the more effective of the French drain alternatives. Finally, results suggest that OU 2 Alternative (e) appears to be the most effective under all of the parameter variations considered in this analysis.

A.8 Additional Model Uncertainty

In addition to uncertainty in model forecasts associated with the assumed model input parameters, uncertainty is also associated with the methodology used to estimate dissolved metals loading to streams from groundwater flow model estimates. As discussed in Section A.4, simulated flow estimates of groundwater discharge to streams, and surface water leakage to underlying groundwater, are paired with analytical data from surface water sampling and groundwater monitoring well sampling. This methodology assumes that (a) dissolved zinc concentrations measured in monitoring wells and piezometers near streams are representative of the concentrations actually being discharged to the stream, and (b) a given set of samples collected during a discrete quarterly sampling event are representative of dissolved zinc concentrations over some range of time (e.g., over the baseflow or spring runoff period). Insufficient data are available with which to quantify the magnitude of uncertainty that these assumptions may introduce into model forecasts.

One final area of uncertainty in the modeling results originates from site characteristics that may be changed by remedial activities that are not explicitly included in the modeling assumptions. One example is that extensive remedial activities, such as surface water collection and treatment in the Upper Coeur d'Alene River Basin, may have significant effects on the magnitude and timing of stream flow in the SFCDR within OU 2. Changes to surface water flows and associated changes to river stage will affect groundwater conditions to some degree. These types of changes to site conditions have not been evaluated during the SFCDR Watershed modeling effort; they would likely have a relatively minor effect on remedy effectiveness.

A.9 References

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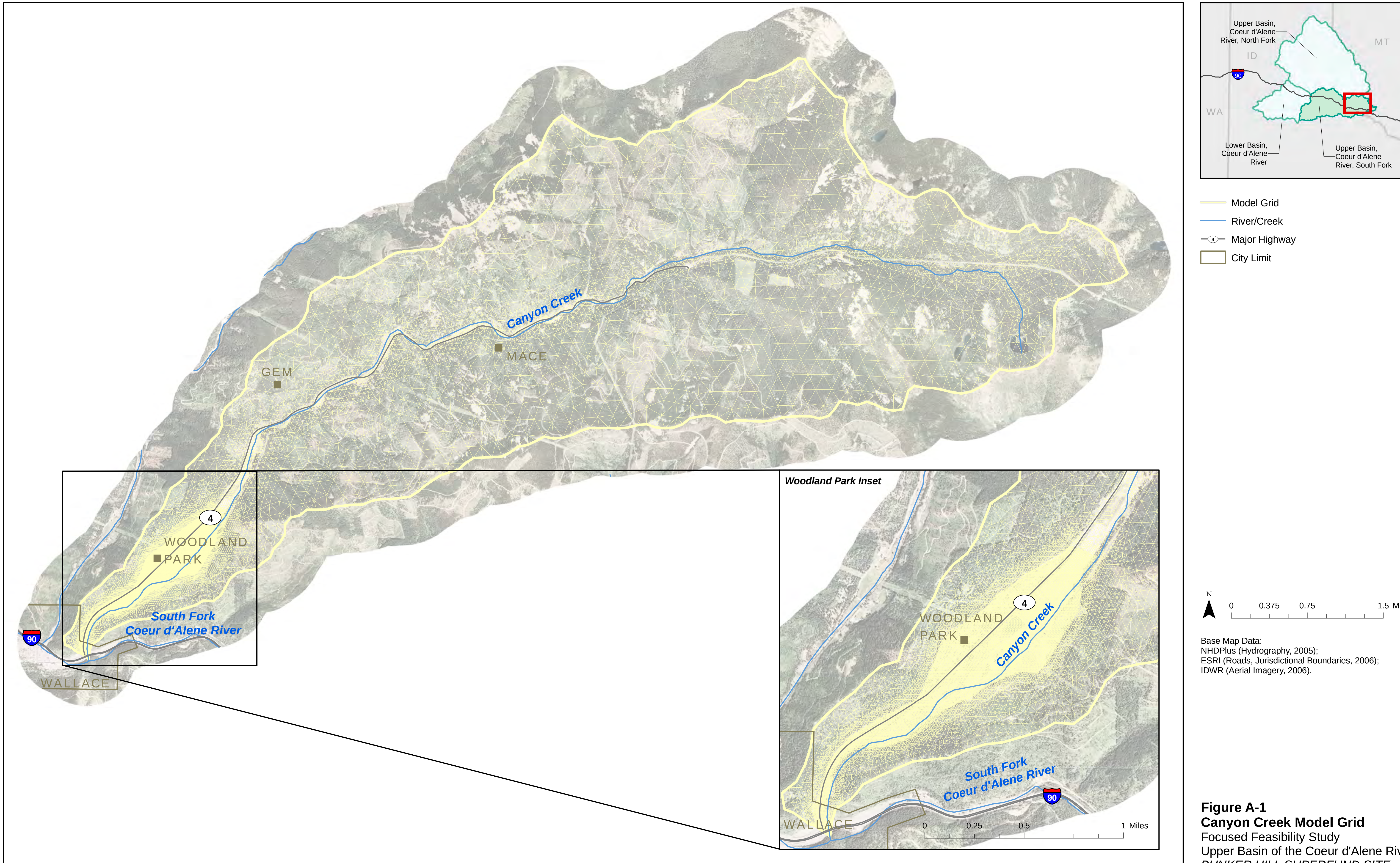
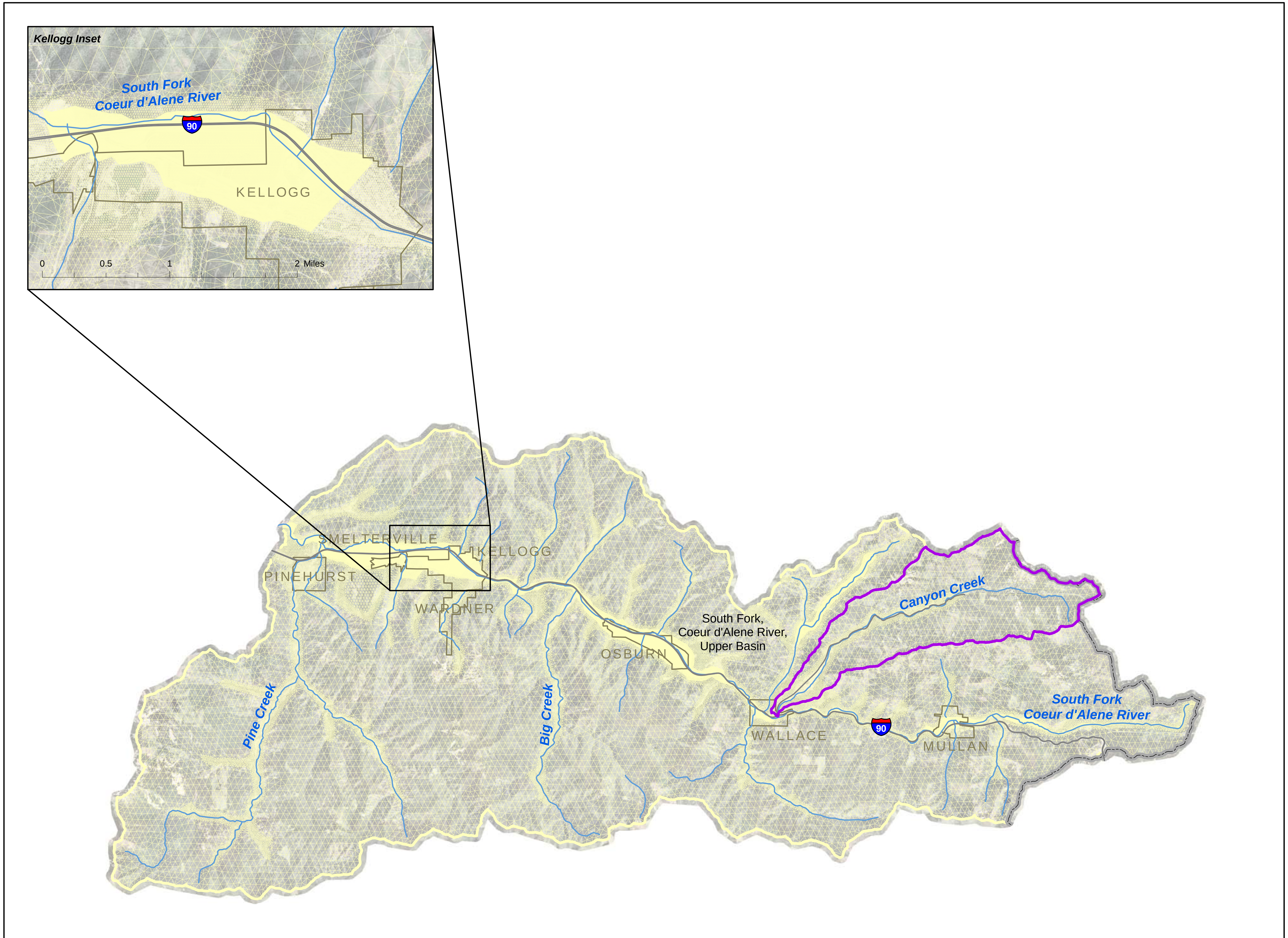
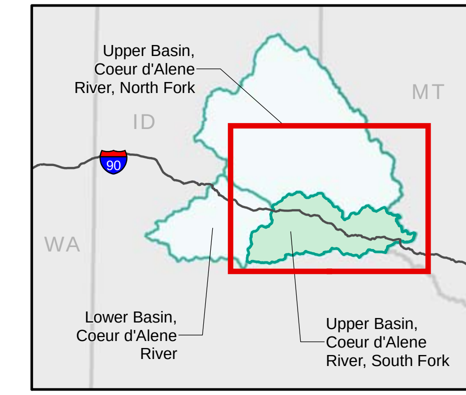
Figures



Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-1
Canyon Creek Model Grid
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE



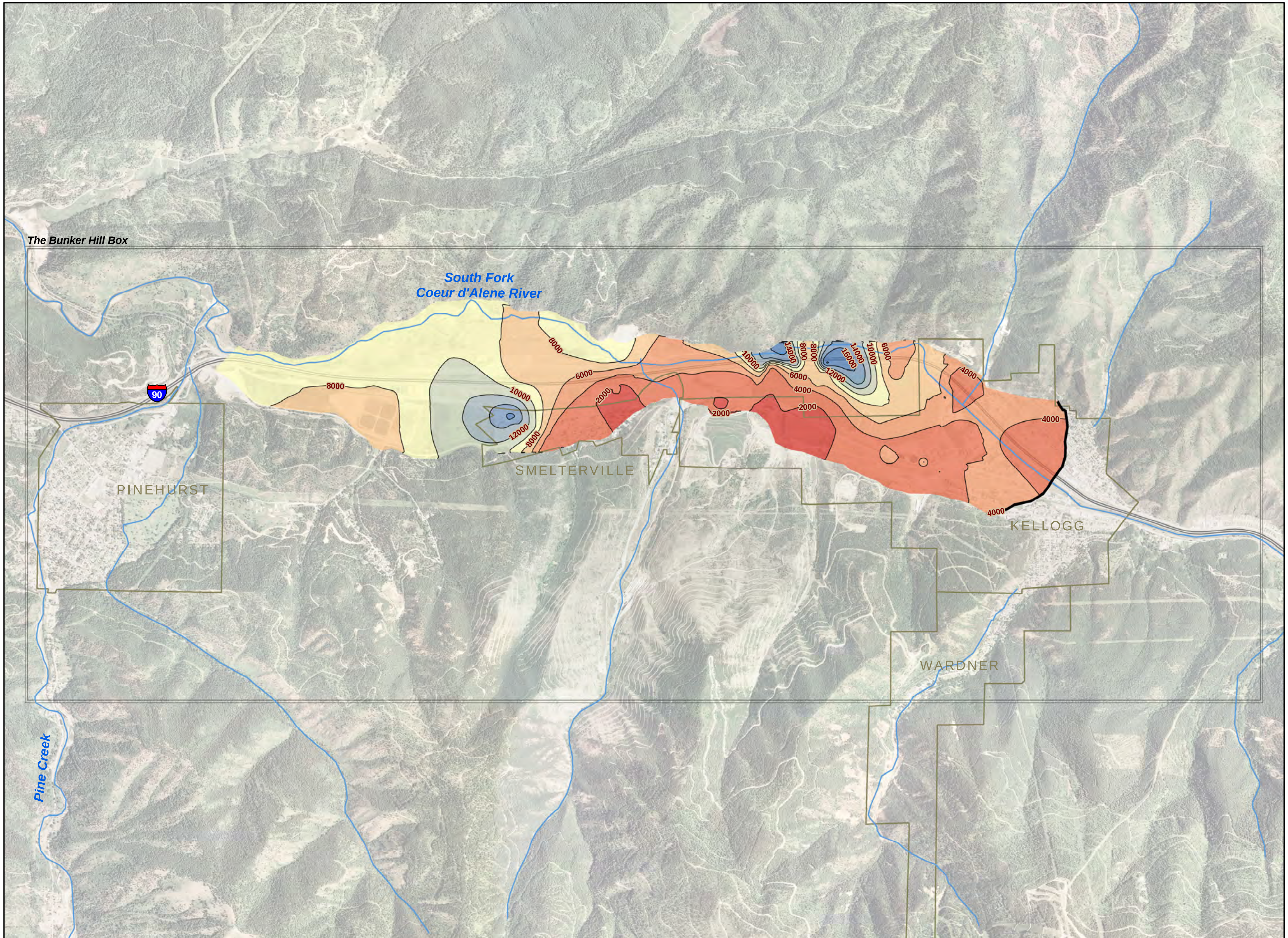


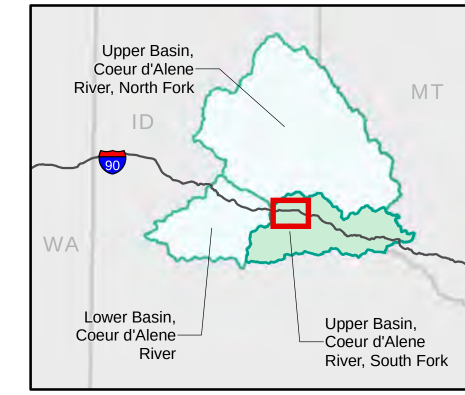
Model Grid
River/Creek
Canyon Creek Watershed
City Limit
State Boundary

N
0 1 2 4 Miles

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-2
SFCDR Model Grid
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE





Approximate Extent of Confining Unit

Transmissivity Contour
(2000-ft²/day interval)

Transmissivity (feet²/day)

- < 2,000
- 2,000 to 4,000
- 4,000 to 6,000
- 6,000 to 8,000
- 8,000 to 10,000
- 10,000 to 12,000
- 12,000 to 14,000
- 14,000 to 16,000
- > 16,000

River/Creek

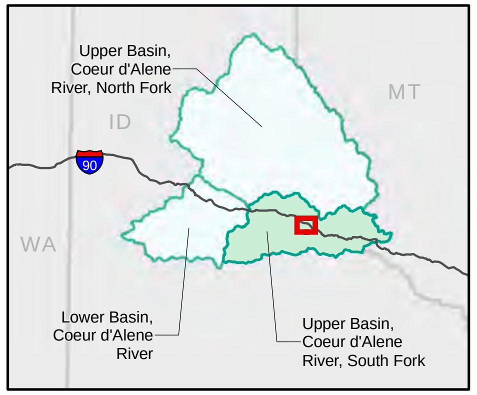
City Limit

N

0 0.125 0.25 0.5 Miles

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-3
Upper Aquifer Transmissivity, Bunker Hill Box
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE



Transmissivity Contour (5000-ft^2/day interval)

Transmissivity (feet^2/day)

- > 5,000
- 5,000 to 10,000
- 10,000 to 15,000
- 15,000 to 20,000
- 20,000 to 25,000
- 25,000 to 30,000
- 30,000 to 35,000
- 35,000 to 40,000
- 40,000 to 45,000
- 45,000 to 50,000
- 50,000 to 55,000
- 55,000 to 60,000
- 60,000 to 65,000
- 65,000 to 70,000
- 70,000 to 75,000
- > 75,000
- River/Creek
- City Limit

N

0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-4
Total Aquifer Transmissivity, Osburn Flats
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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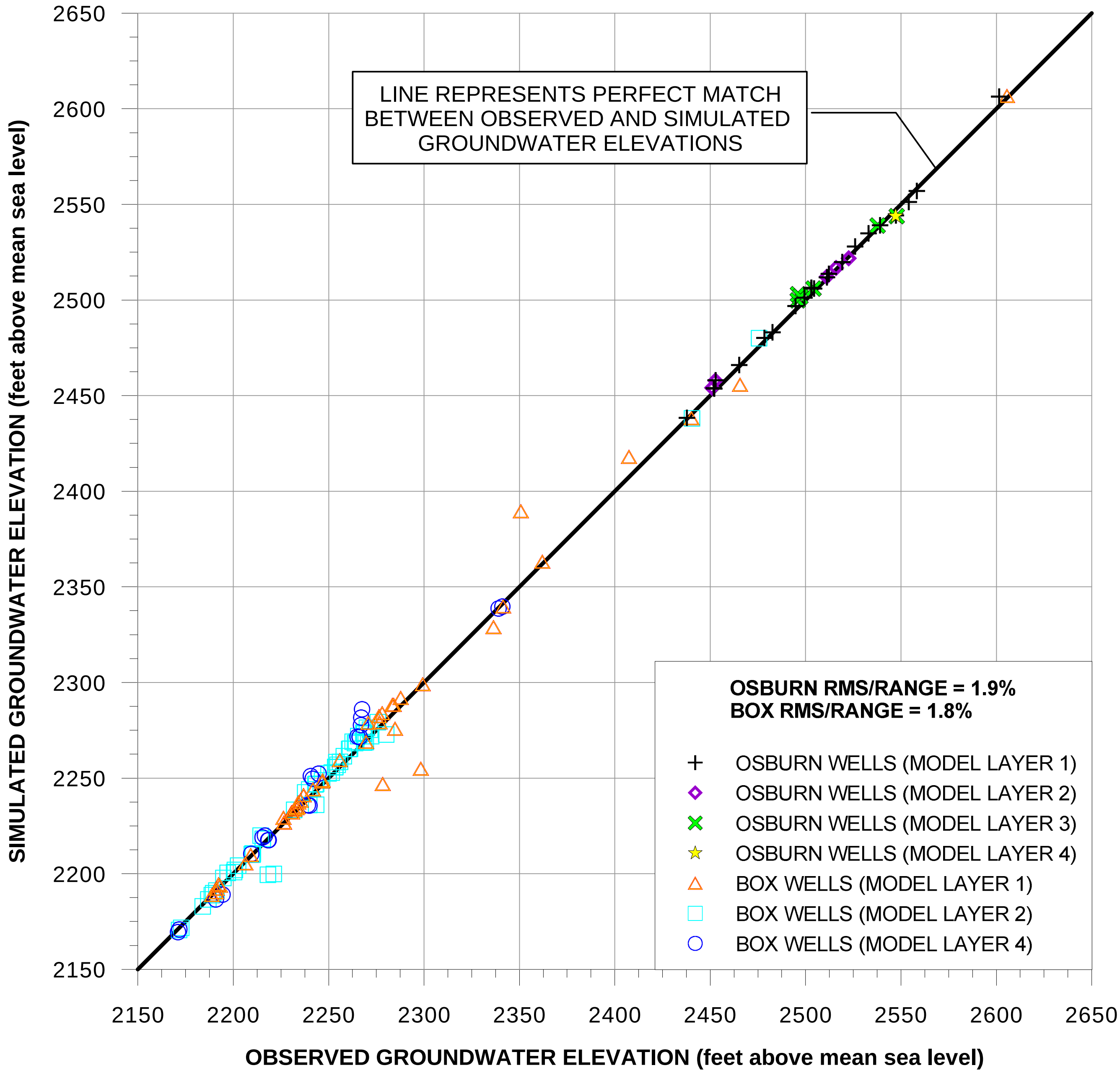
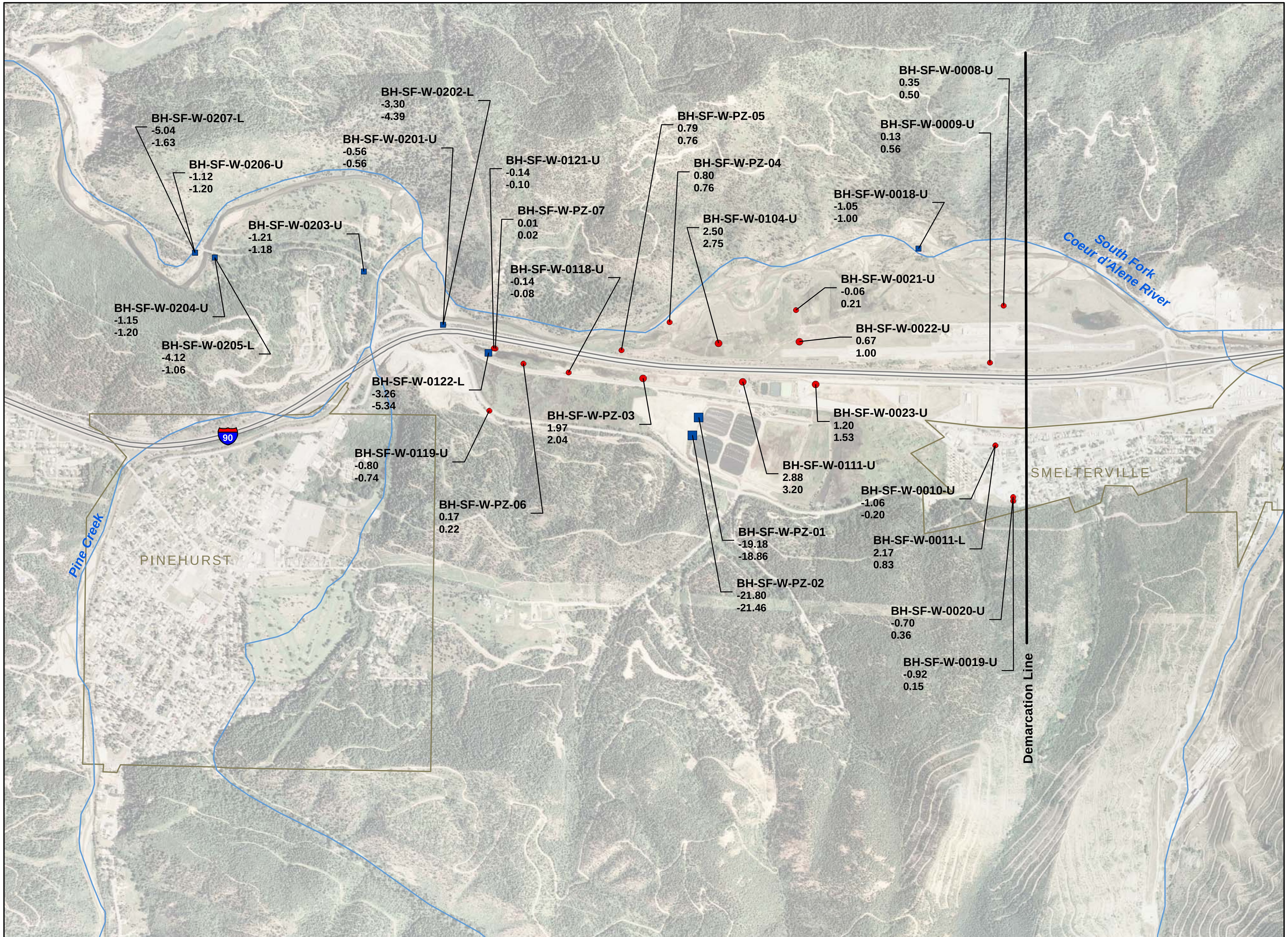
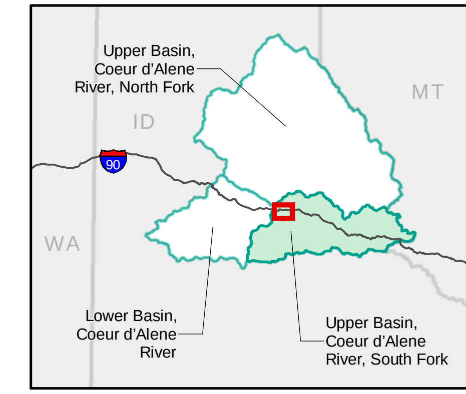


Figure A-5
Simulated versus Observed Groundwater Elevations – Baseflow Conditions

Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

Note:
RMS/Range is a measure of model calibration and is equal to the root mean squared error divided by the range in measured groundwater elevation.





Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

BH-SF-W-0021-U (Site ID)
-0.06 (Previous Residual)
0.21 (Current Residual[1])

N

0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Notes:
1. Residual is equal to simulated groundwater elevation minus measured groundwater elevation.
2. The demarcation line represents the area of overlap between two connected figures such that data for the previous/subsequent figure are not displayed on the current figure.

Figure A-6a
Residuals between Measured and Simulated Groundwater Elevations, Western Bunker Hill Box, Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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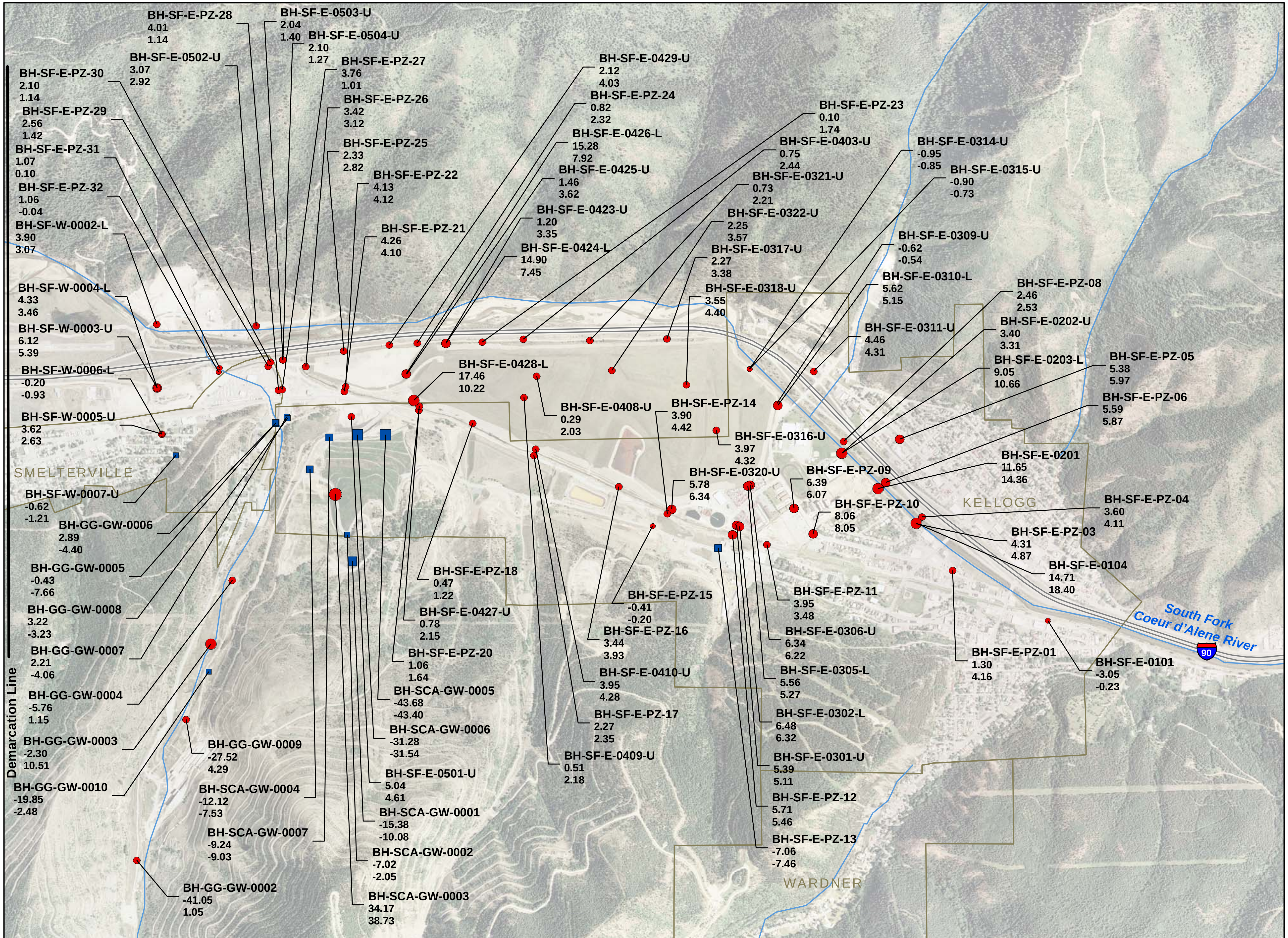

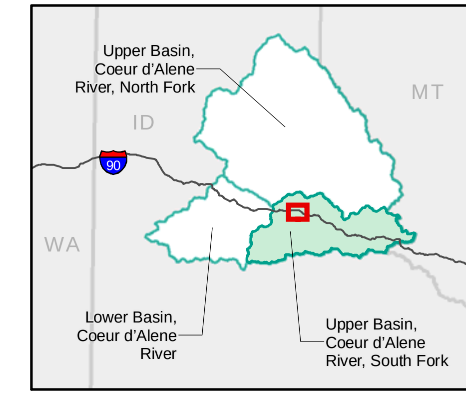

Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

BH-SF-E-0101 (Site ID)
-3.05 (Previous Residual)
-0.23 (Current Residual[1])

N

0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Notes:
1. Residual is equal to simulated groundwater elevation minus measured groundwater elevation.
2. The demarcation line represents the area of overlap between two connected figures such that data for the previous/subsequent figure are not displayed on the current figure.

Figure A-6b
Residuals between Measured and Simulated Groundwater Elevations, Eastern Bunker Hill Box, Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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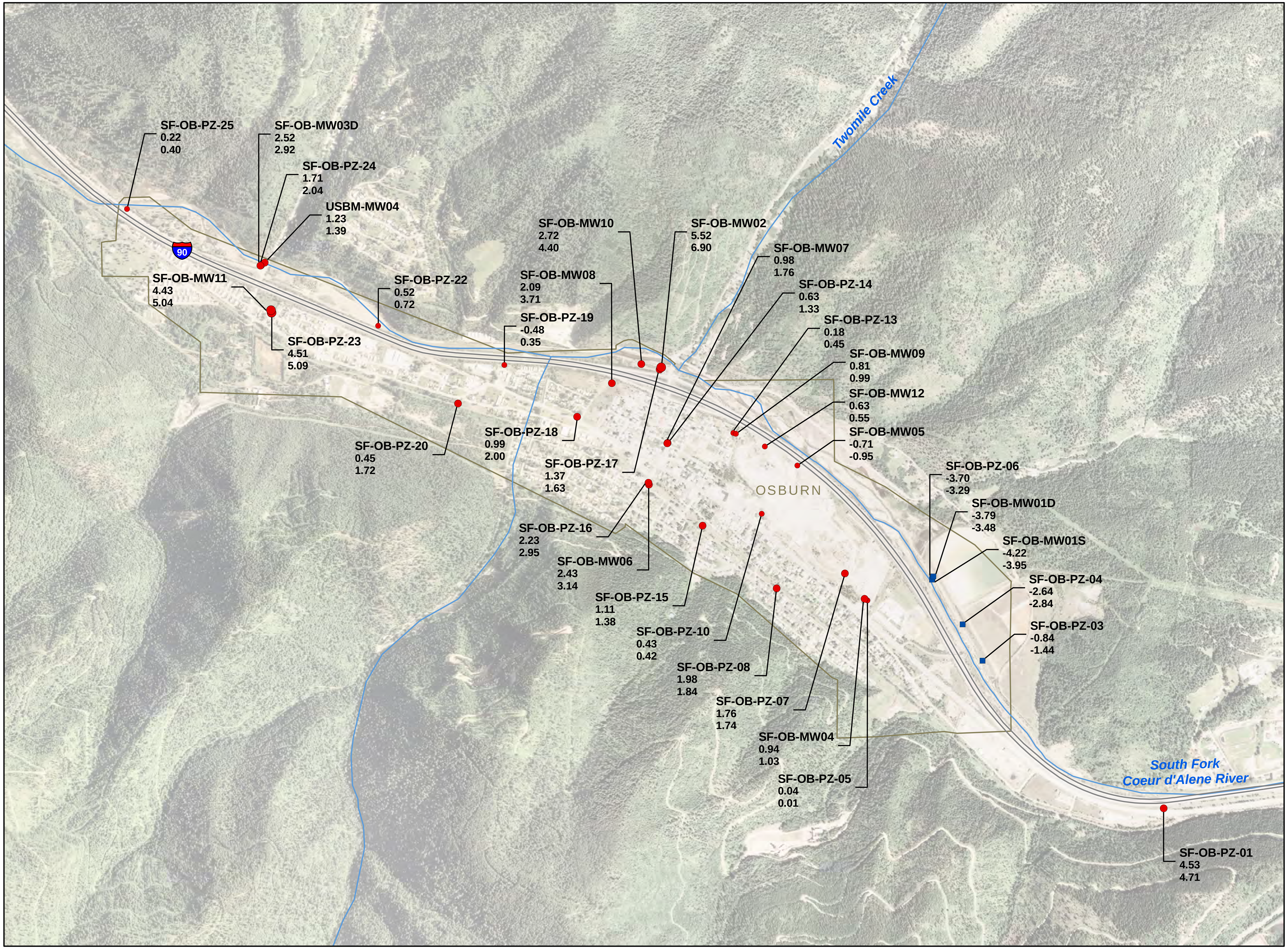
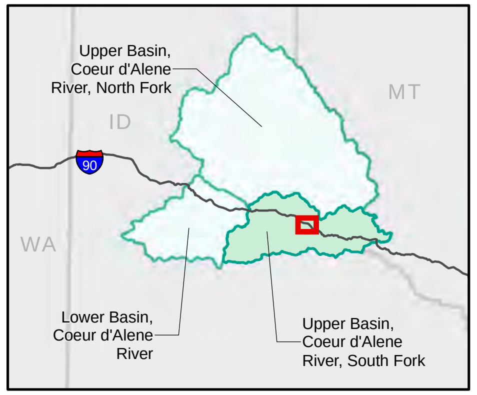




Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

SF-OB-PZ-04 (Site ID)
-2.64 (Previous Residual)
-2.84 (Current Residual[1])

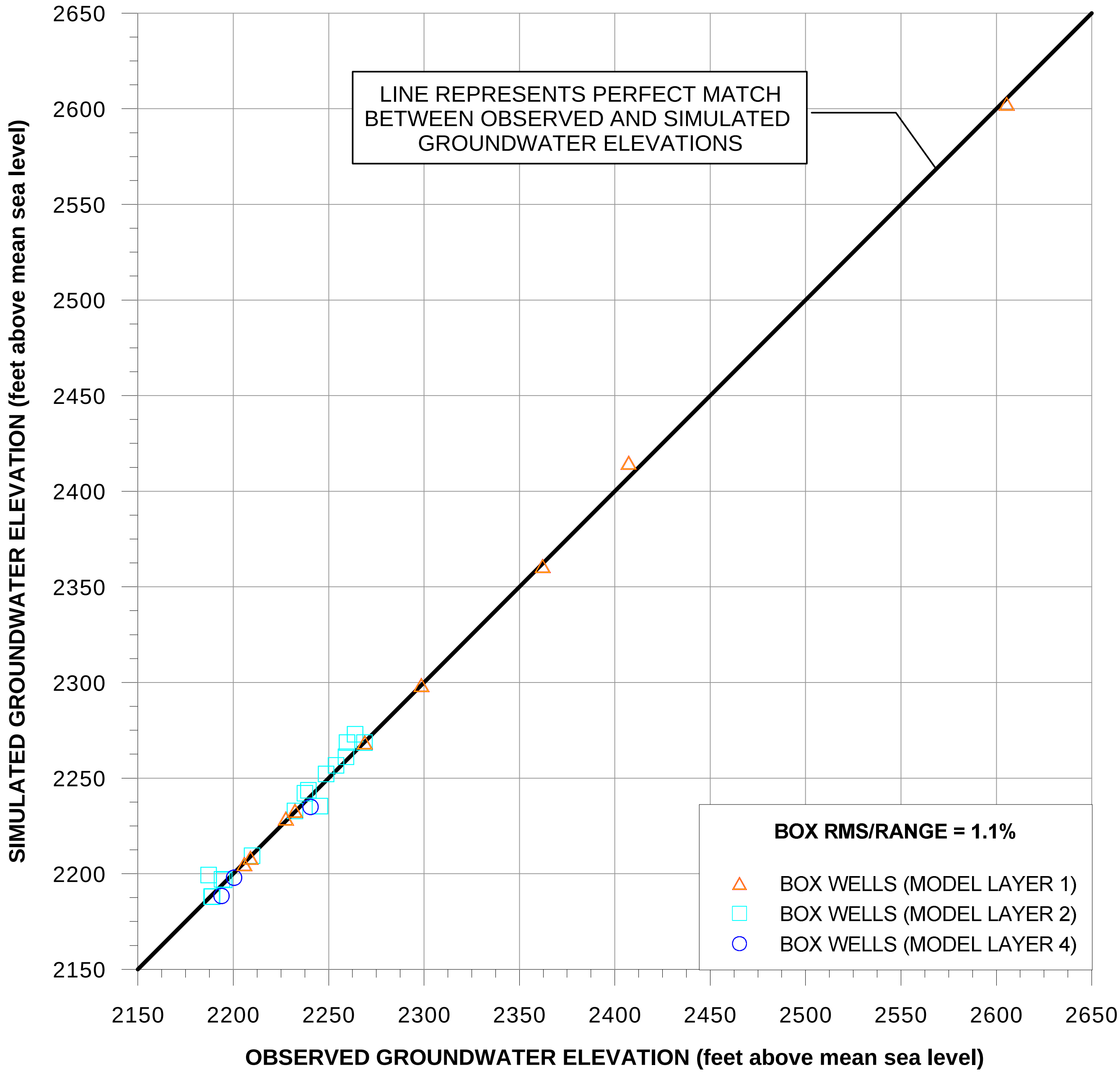
N
0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Note:
Residual is equal to simulated groundwater elevation minus measured groundwater elevation.

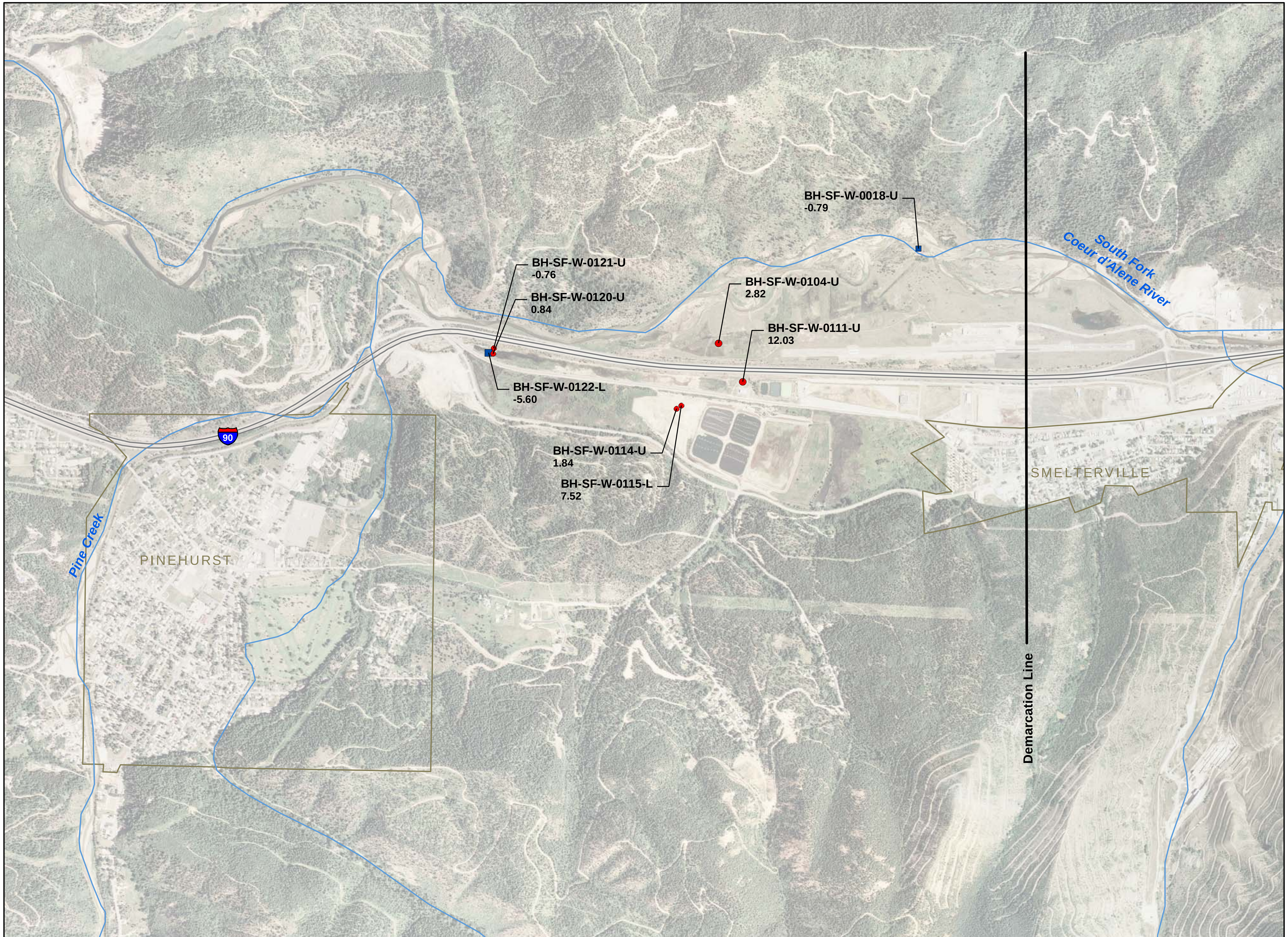
Figure A-6c
Residuals between Measured and Simulated Groundwater Elevations, Osburn Flats, Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

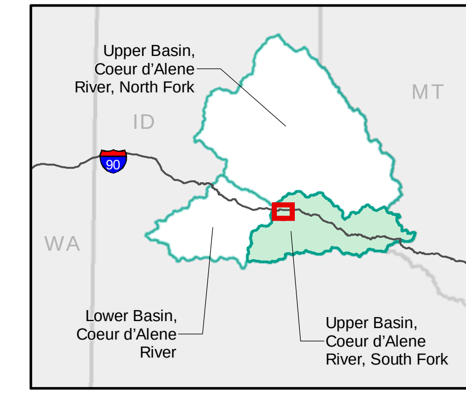
EPA



Note:
RMS/Range is a measure of model calibration and is equal to the root mean squared error divided by the range in measured groundwater elevation.

Figure A-7
Simulated versus Observed Groundwater Elevations – 7Q10 Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE





Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

BH-SF-W-0018-U (Site ID)
-0.79 (7Q10 Residual[1])

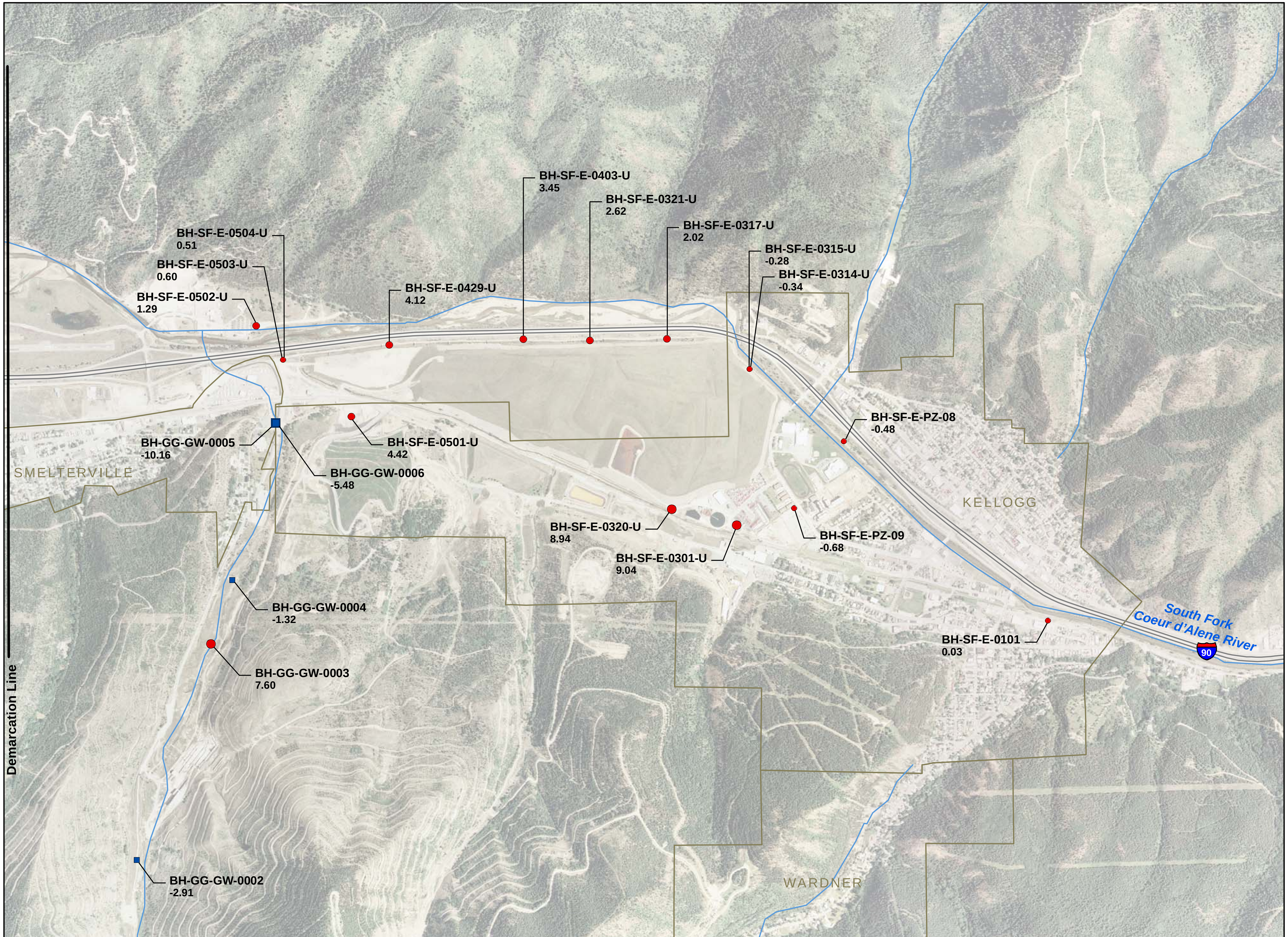
N
0 500 1,000 2,000 Feet

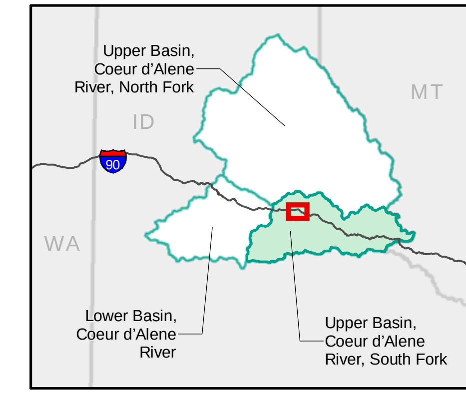
Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Notes:
1. Residual is equal to simulated groundwater elevation minus measured groundwater elevation.
2. The demarcation line represents the area of overlap between two connected figures such that data for the previous/subsequent figure are not displayed on the current figure.

Figure A-8a
Residuals between Measured and Simulated Groundwater Elevations, Western Bunker Hill Box, 7Q10 Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA





Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

BH-SF-E-0101 (Site ID)
0.03 (7Q10 Residual[1])

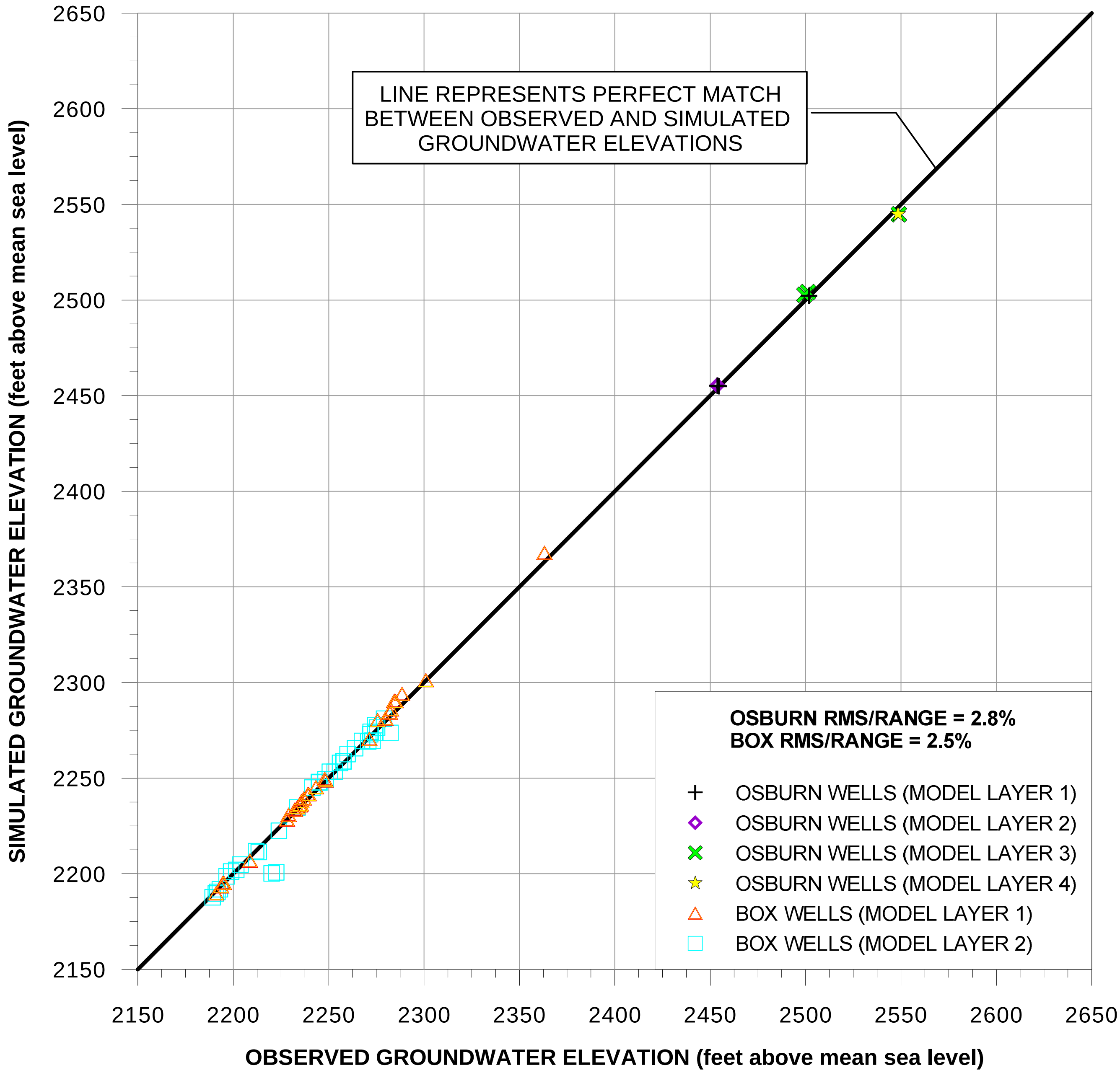
N
0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Notes:
1. Residual is equal to simulated groundwater elevation minus measured groundwater elevation.
2. The demarcation line represents the area of overlap between two connected figures such that data for the previous/subsequent figure are not displayed on the current figure.

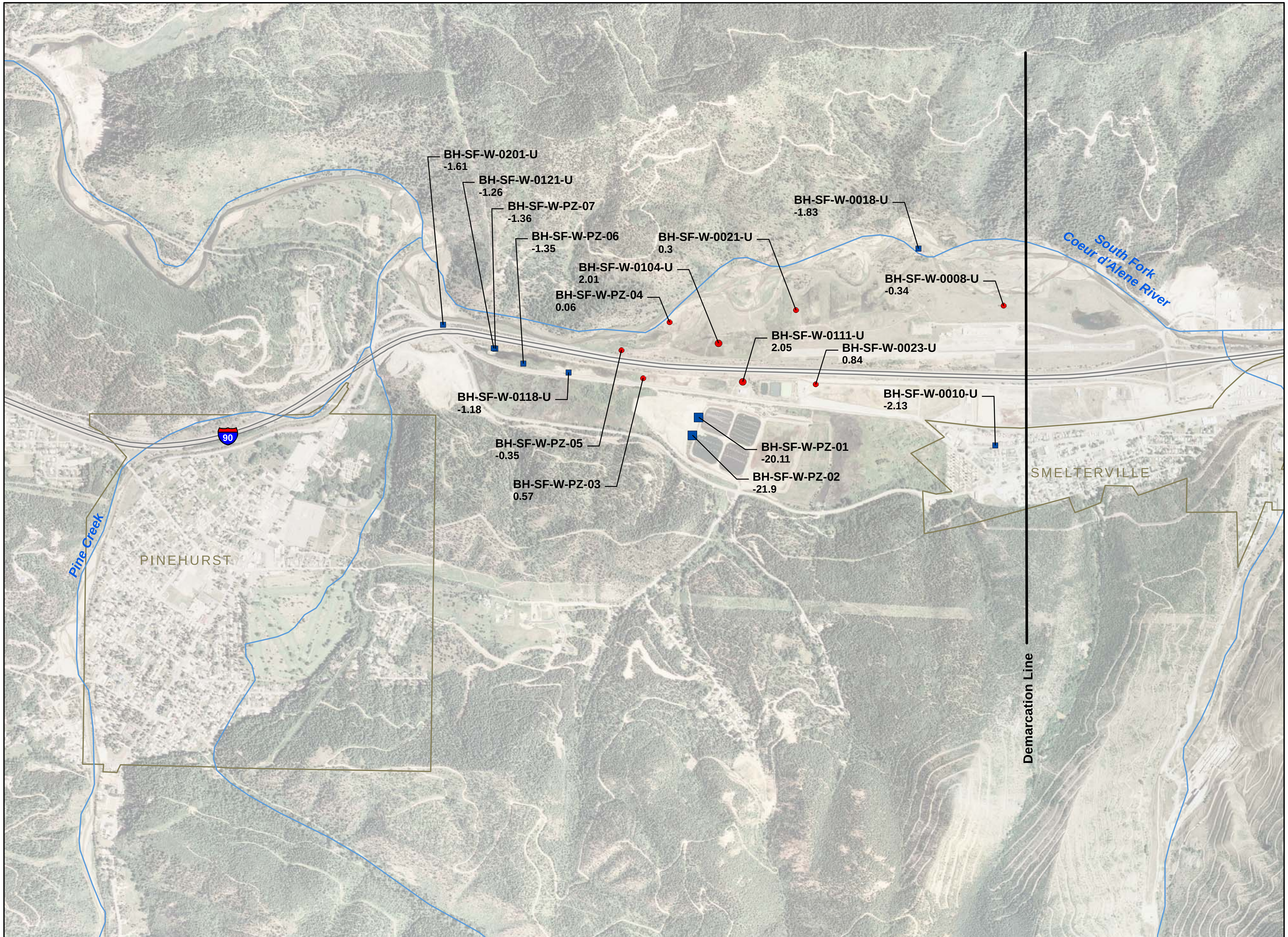
Figure A-8b
Residuals between Measured and Simulated Groundwater Elevations, Eastern Bunker Hill Box, 7Q10 Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

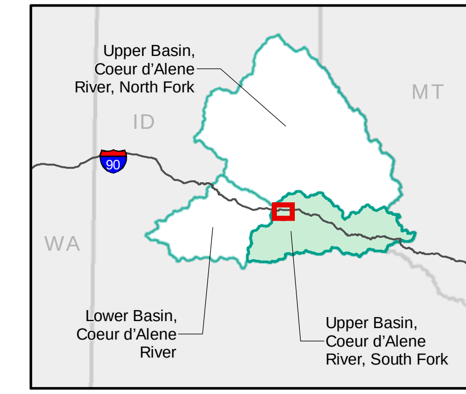
EPA



Note:
RMS/Range is a measure of model calibration and is equal to the root mean squared error divided by the range in measured groundwater elevation.

Figure A-9
Simulated versus Observed Groundwater Elevations – 90th Percentile Flow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE





Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

BH-SF-W-0010-U (Site ID)
-2.13 (90th Percentile Flow Residual[1])

N

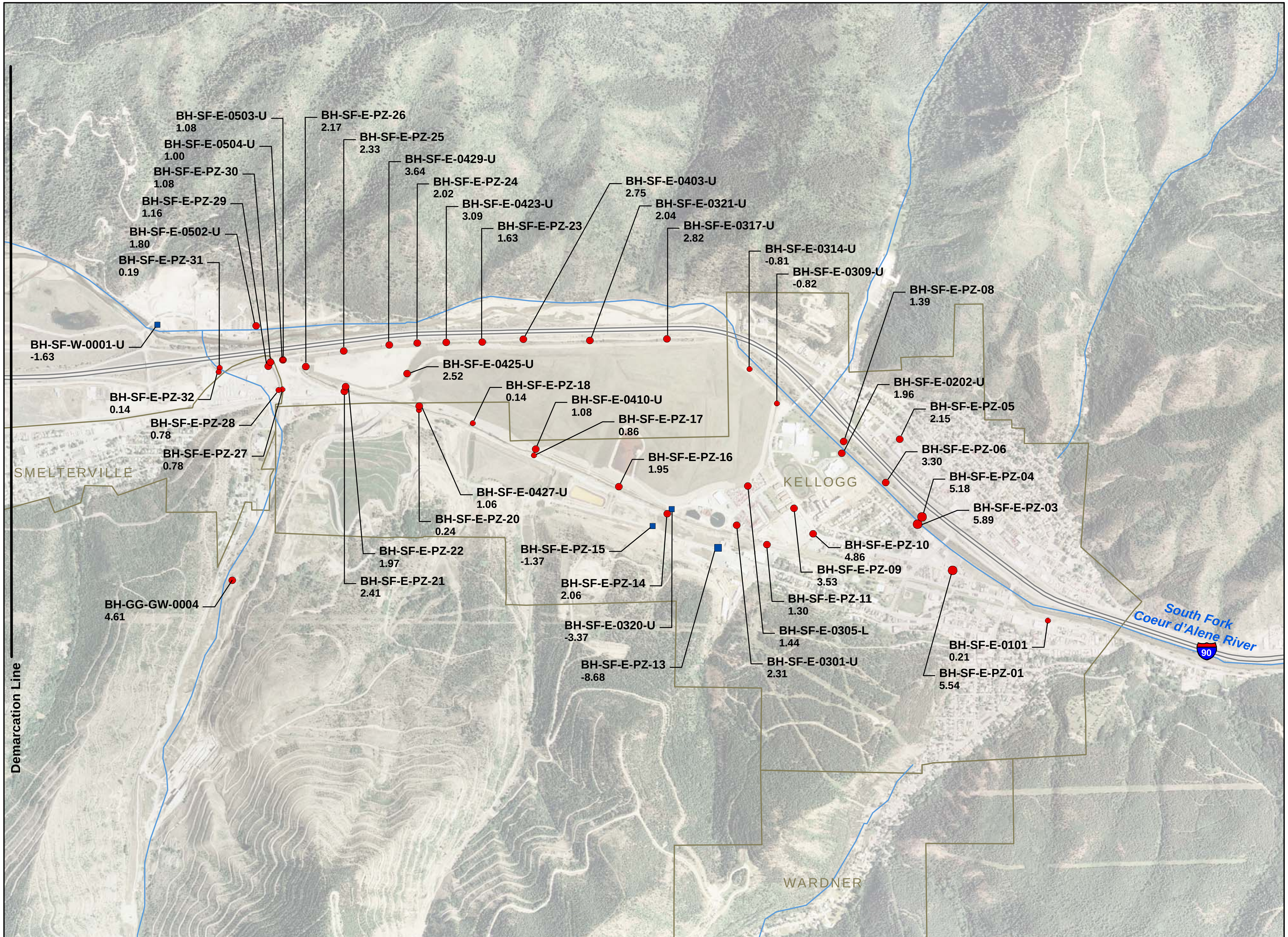
0 500 1,000 2,000 Feet

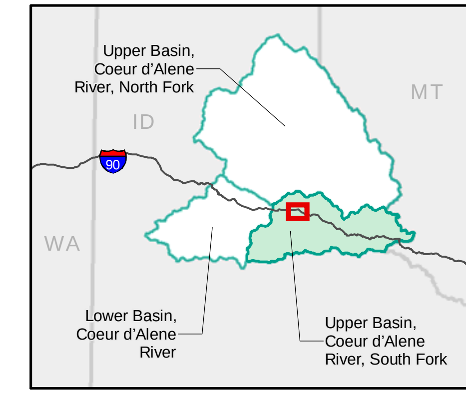
Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Notes:
1. Residual is equal to simulated groundwater elevation minus measured groundwater elevation.
2. The demarcation line represents the area of overlap between two connected figures such that data for the previous/subsequent figure are not displayed on the current figure.

Figure A-10a
Residuals between Measured and Simulated Groundwater Elevations, Western Bunker Hill Box, 90th Percentile Flow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA





Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

BH-SF-E-0101 (Site ID)
0.21 (90th Percentile Flow Residual[1])

N
0 500 1,000 2,000 Feet

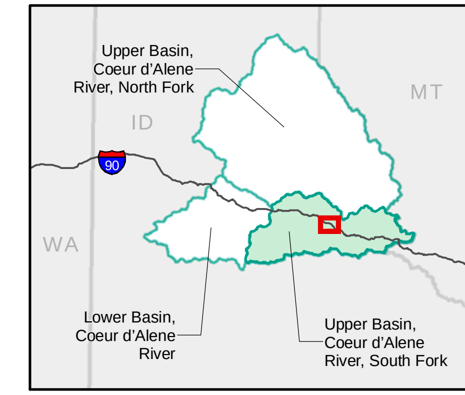
Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Notes:
1. Residual is equal to simulated groundwater elevation minus measured groundwater elevation.
2. The demarcation line represents the area of overlap between two connected figures such that data for the previous/subsequent figure are not displayed on the current figure.

Figure A-10b
Residuals between Measured and Simulated Groundwater Elevations, Eastern Bunker Hill Box, 90th Percentile Flow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA

\\CASTAIC\PROJ\EPA\CDABASIN_382081\GIS\MAPFILES\FFS\APPENDIXA\FFS_APDXA_OU2ERESIDUAL90FLOWTIER.MXD JCARR3 5/17/2010 13:02:25



Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

SF-OB-MW01D (Site ID)
-3.84 (90th Percentile Flow Residual[1])

N
0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Note:
1. Residual is equal to simulated groundwater elevation minus measured groundwater elevation.

Figure A-10c
Residuals between Measured and Simulated Groundwater Elevations, Osburn Flats, 90th Percentile Flow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

\\CASTAIC\PROJ\EPA\CDABASIN_382081\GIS\MAPFILES\FFS\APPENDIXA\FFS_APDXA_OSBRESIDUAL90FLOWTIER.MXD JCARR3 5/17/2010 13:05:41

EPA

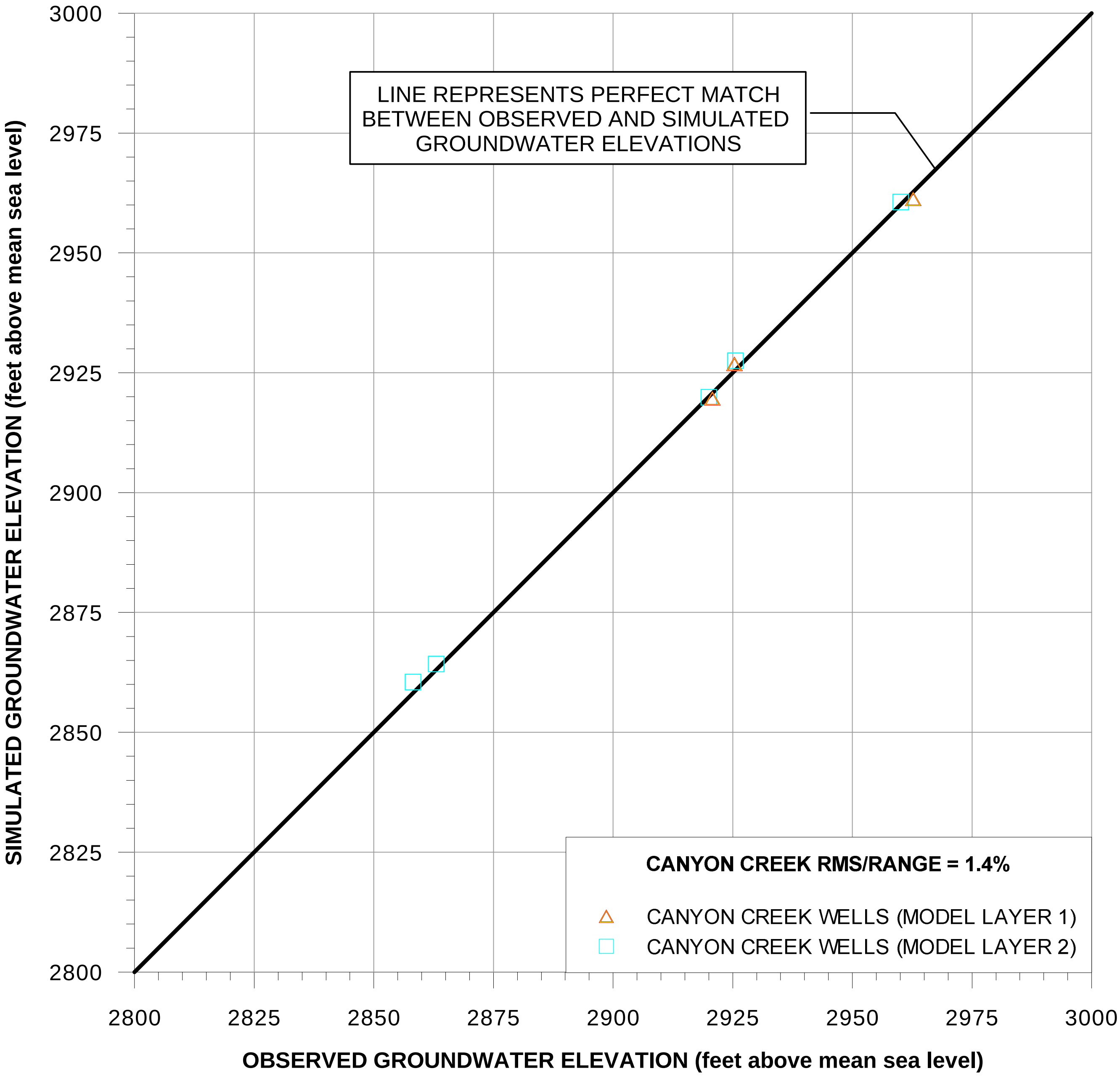
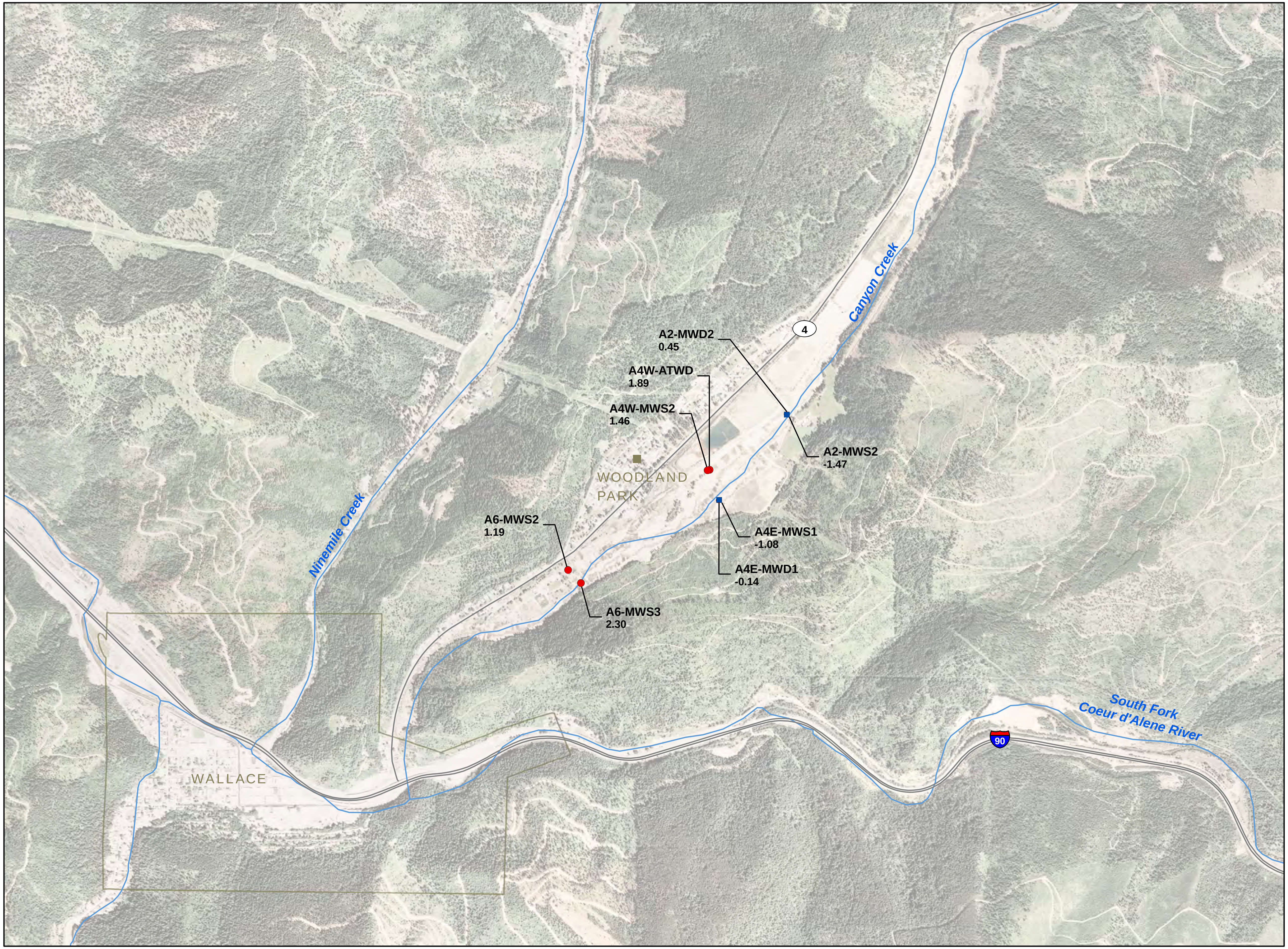
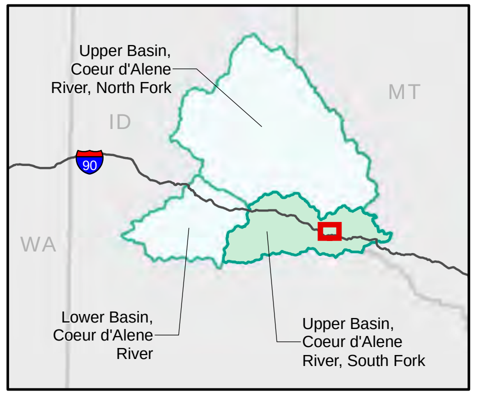


Figure A-11
Simulated versus Observed Groundwater Elevations – Canyon Creek, 90th Percentile Flow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

Note:
RMS/Range is a measure of model calibration and is equal to the root mean squared error divided by the range in measured groundwater elevation.

\\Odin\proj\usepa\323031\BunkerHill\Figures\GRAPHER\2009_12_FEFS_ModelingAppendix\FIGURE_A-11_Scattergram_90_CC.grf





Residual (feet)

- -51 to -25
- -25 to -10
- -10 to -5
- -5 to -1
- -1 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 40
- River/Creek
- City Limit

A2-MWD2 (Site ID)
0.45 (90th Percentile Flow Residual[1])

N
0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Note:
Residual is equal to simulated groundwater elevation minus measured groundwater elevation.

Figure A-12
Residuals between Measured and Simulated Groundwater Elevations, Canyon Creek, 90th Percentile Flow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA

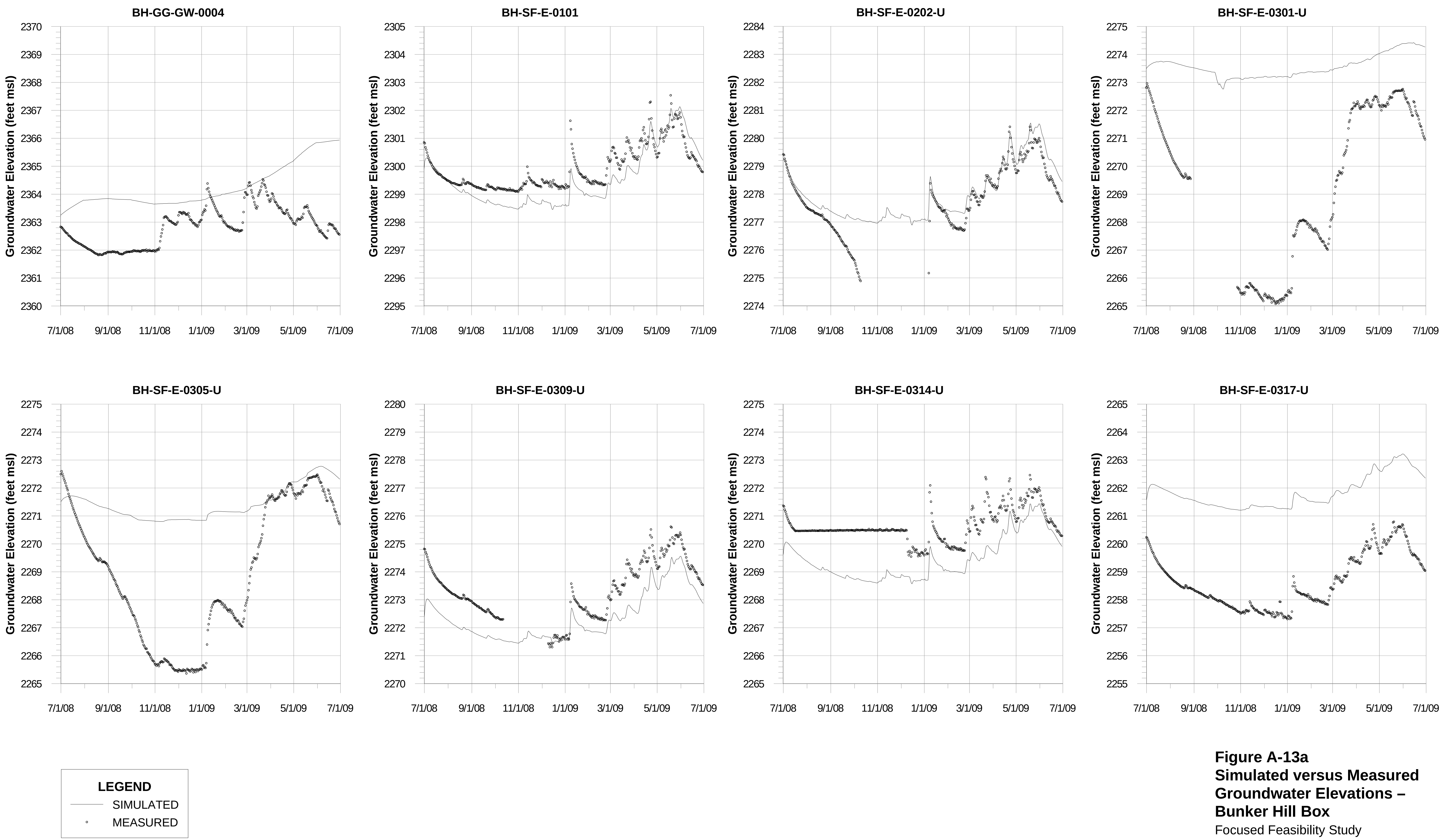


Figure A-13a
Simulated versus Measured Groundwater Elevations – Bunker Hill Box
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

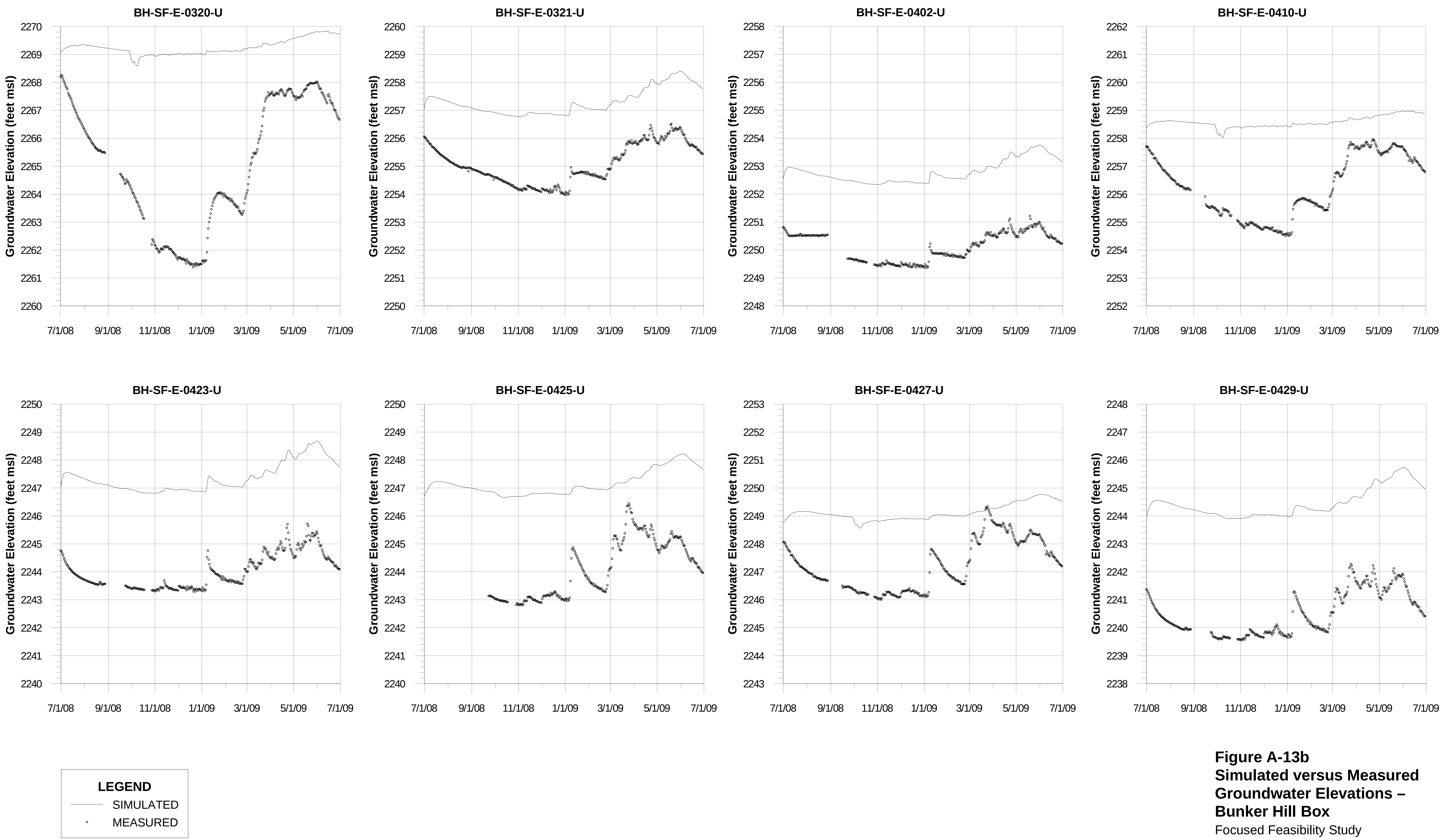
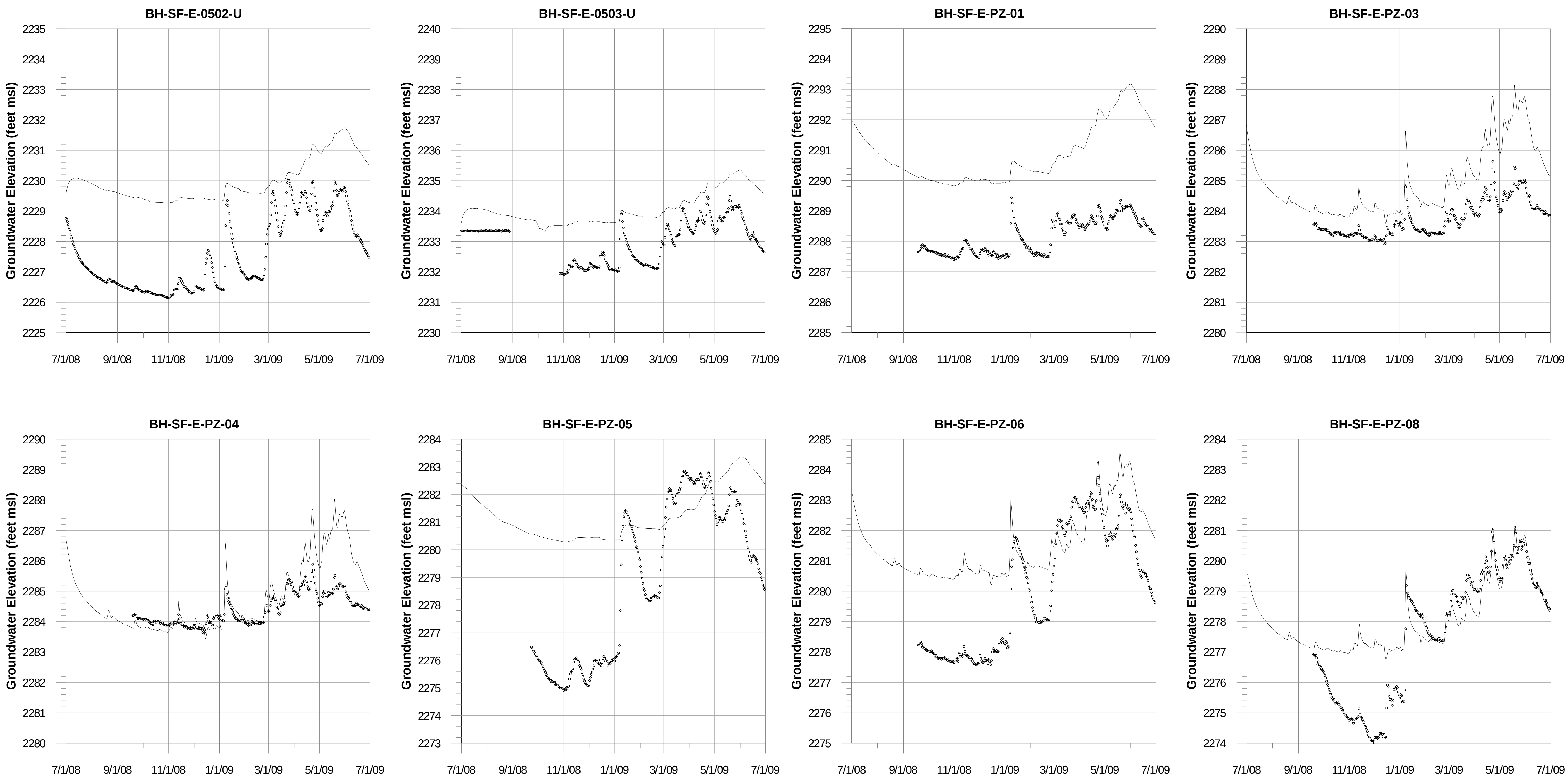


Figure A-13b
Simulated versus Measured Groundwater Elevations – Bunker Hill Box
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE



LEGEND
SIMULATED
MEASURED

Figure A-13c
Simulated versus Measured Groundwater Elevations – Bunker Hill Box
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

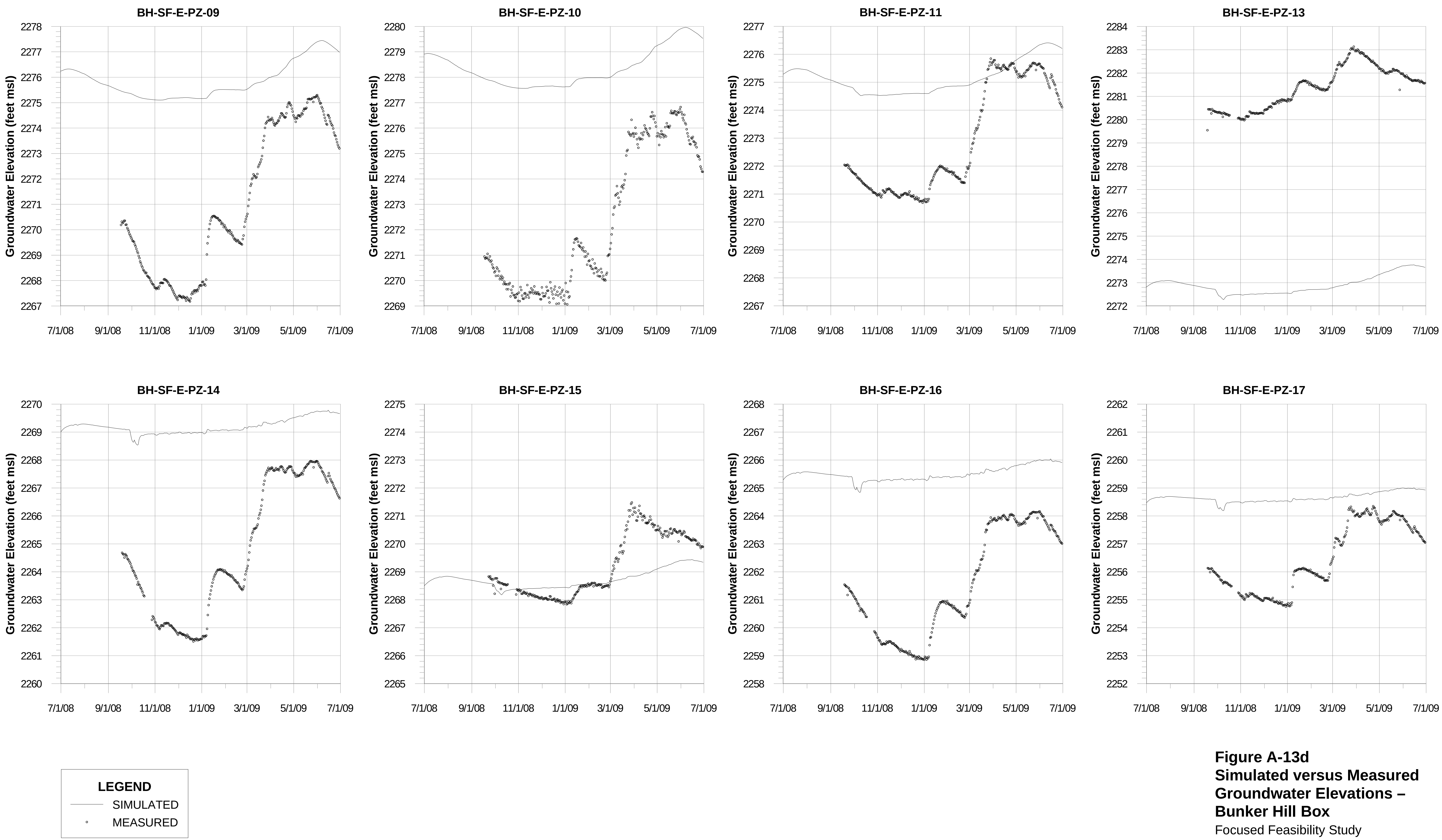


Figure A-13d
Simulated versus Measured Groundwater Elevations – Bunker Hill Box
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

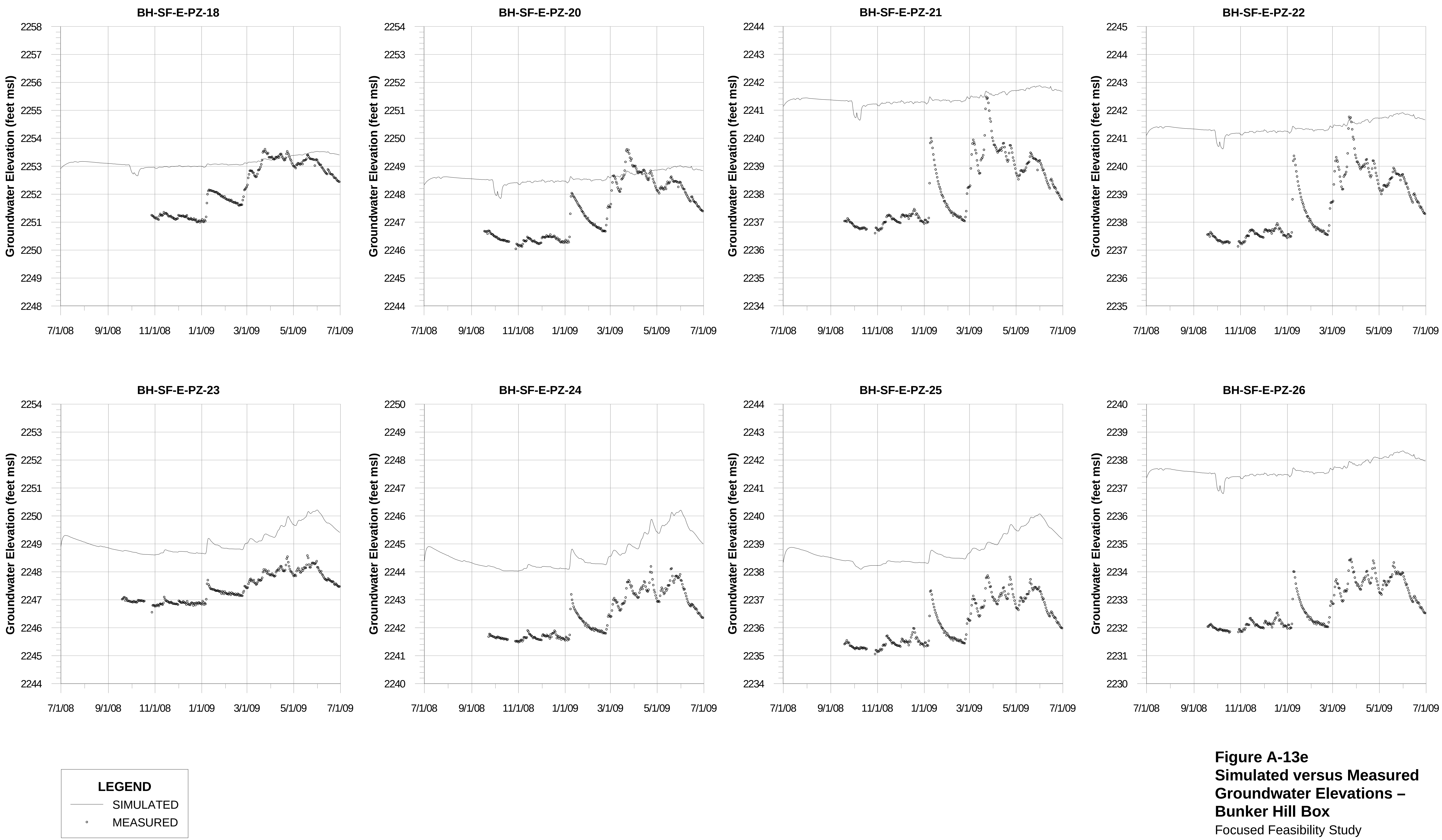


Figure A-13e
Simulated versus Measured Groundwater Elevations – Bunker Hill Box

Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

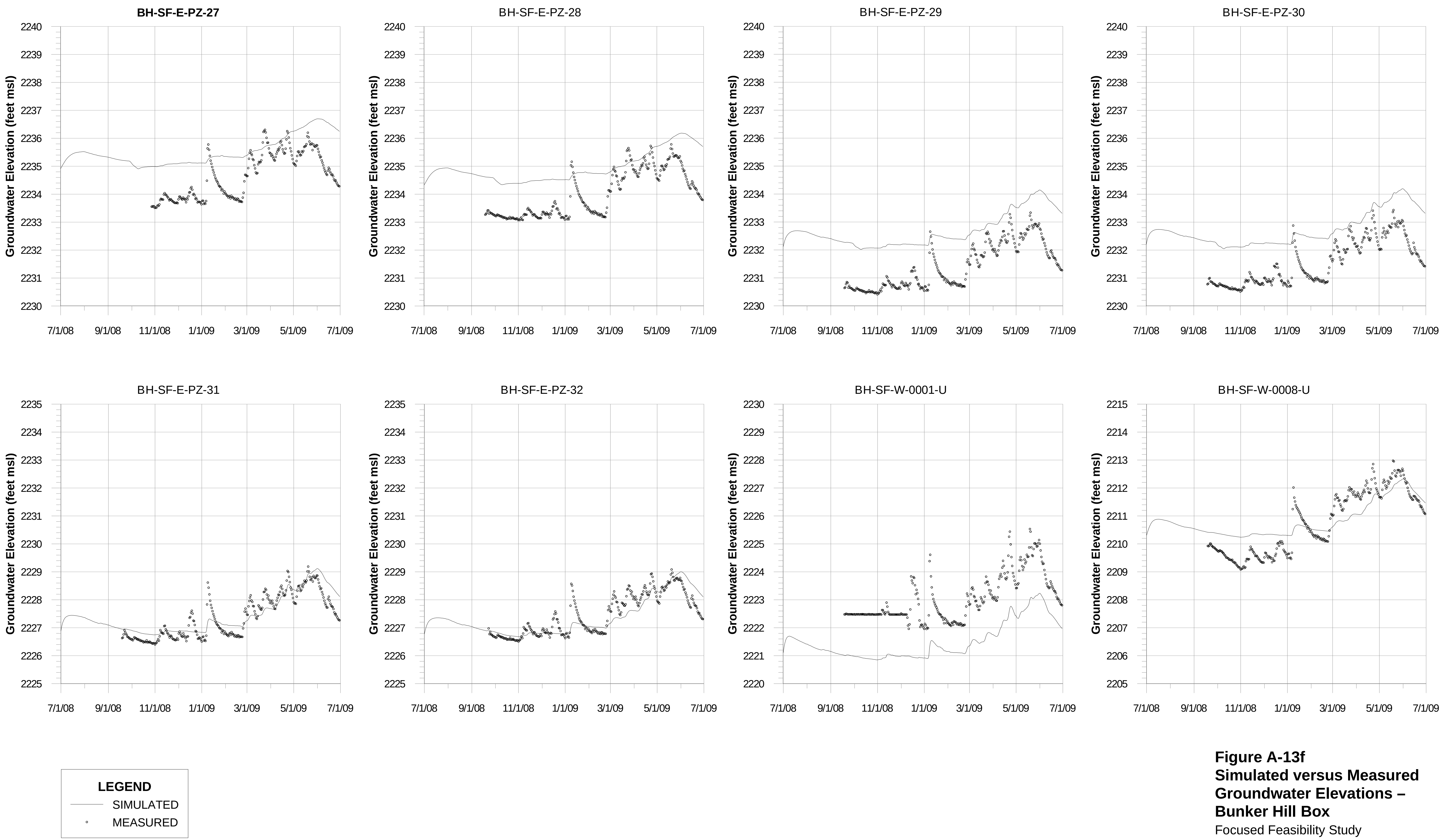


Figure A-13f
Simulated versus Measured Groundwater Elevations – Bunker Hill Box
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

\\Odin\proj\usepa\323031\BunkerHill\Figures\GRAPHER\2009_12_FEFS_ModelingAppendix\FIGURE_A-13f_BoxHydrographs.grf

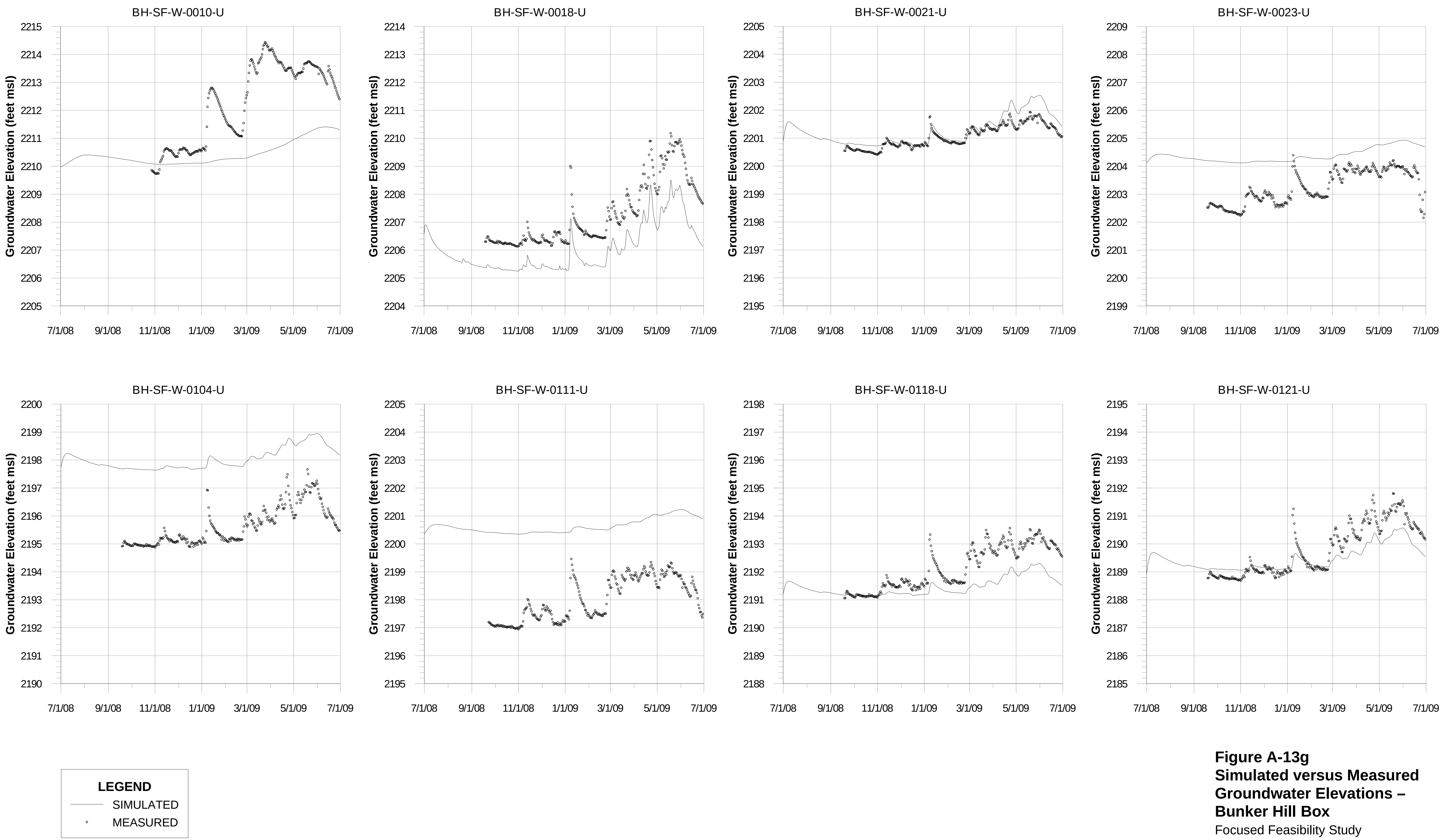
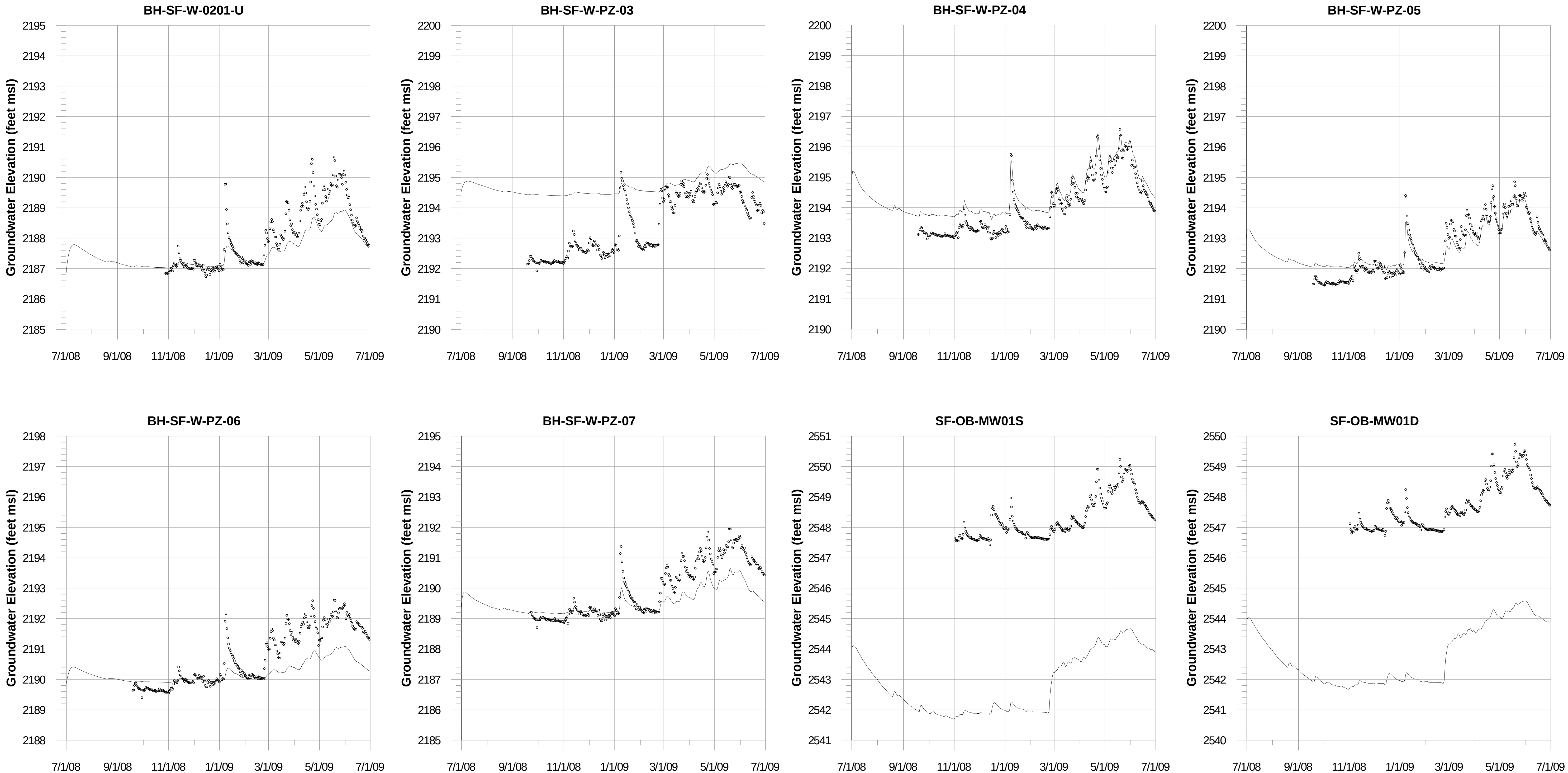


Figure A-13g
Simulated versus Measured Groundwater Elevations – Bunker Hill Box
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE



LEGEND
SIMULATED
MEASURED

Figure A-13h
Simulated versus Measured Groundwater Elevations – Bunker Hill Box/Osburn Flats
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

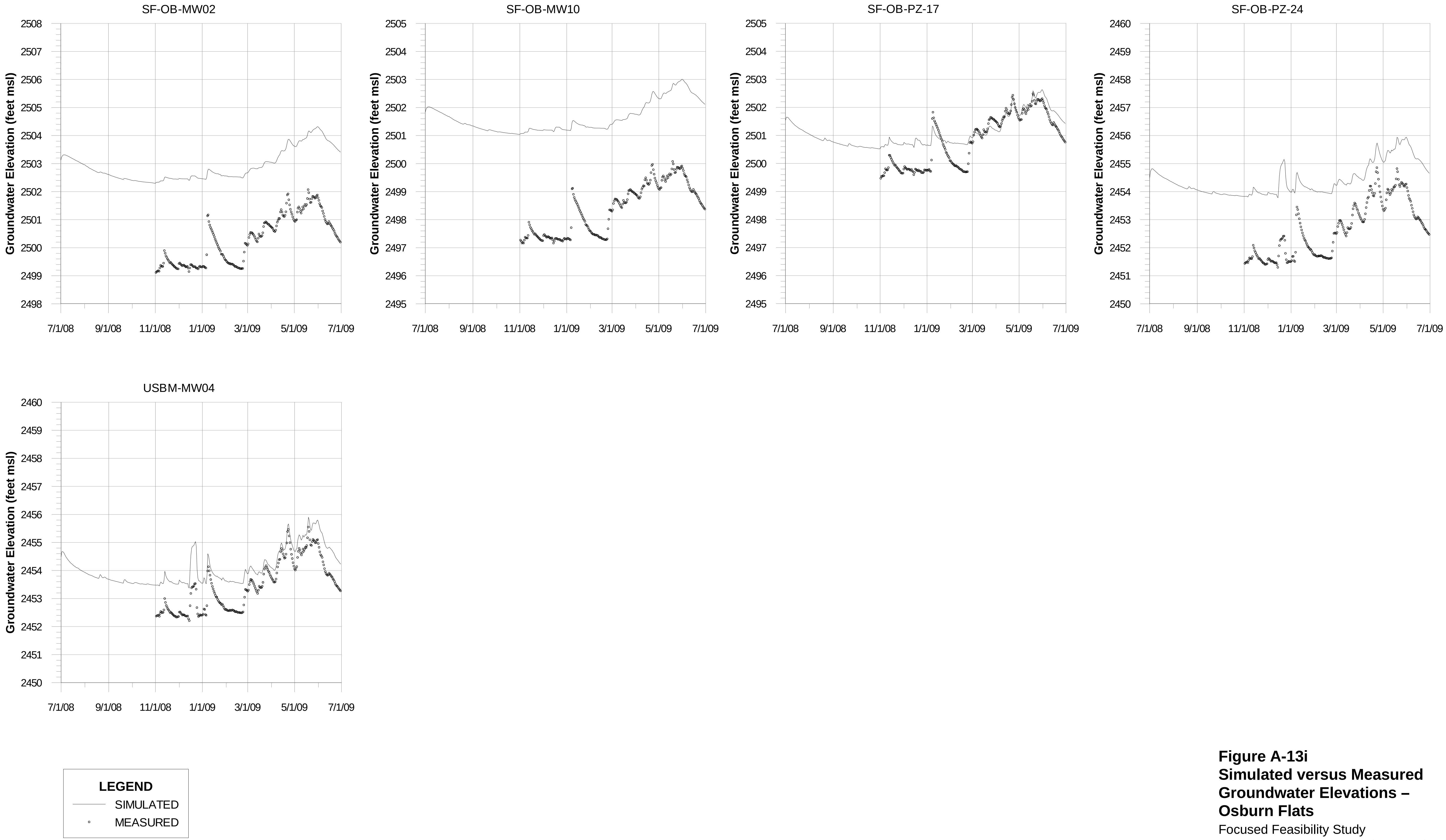


Figure A-13i
Simulated versus Measured Groundwater Elevations – Osburn Flats

Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

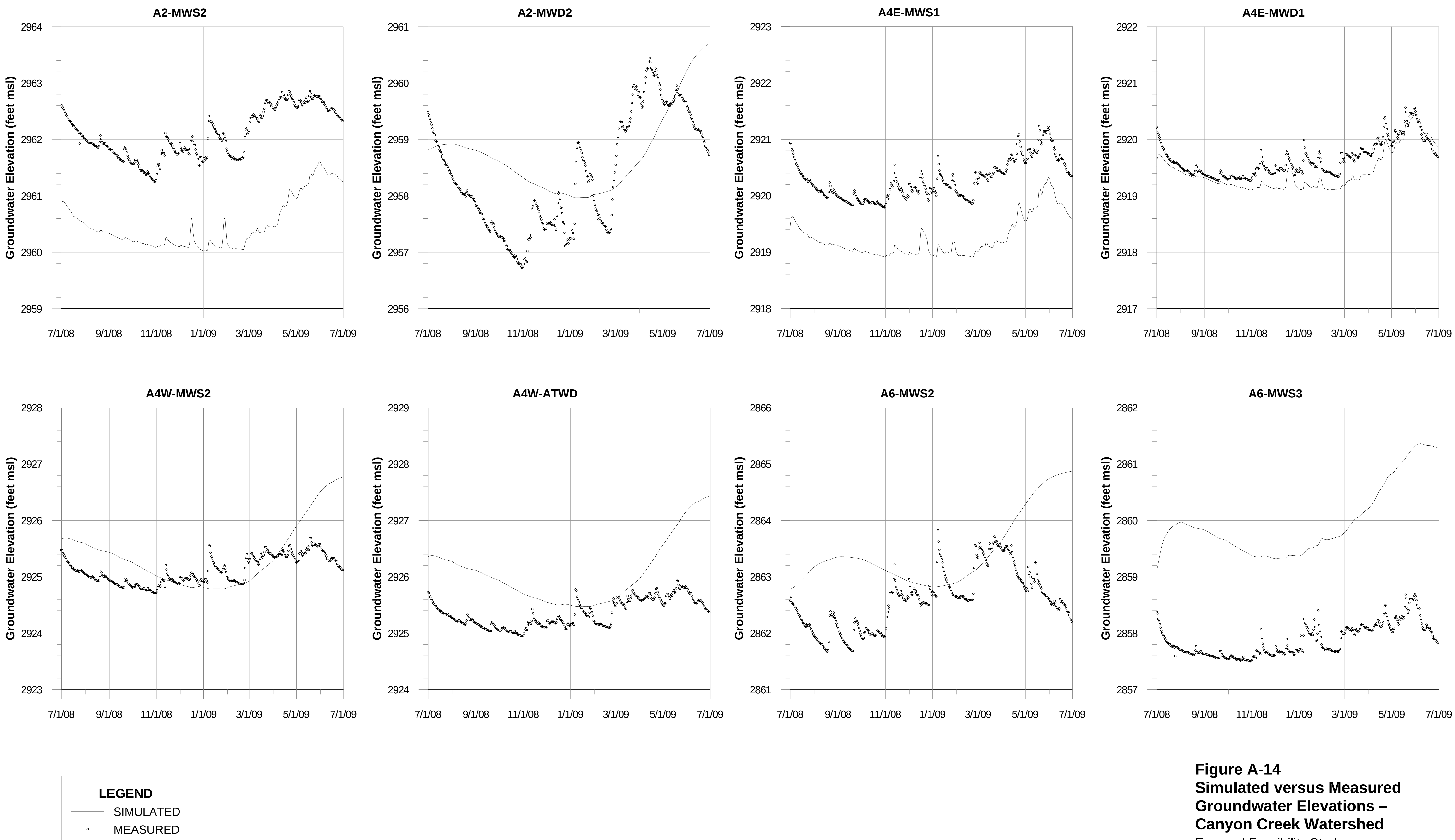
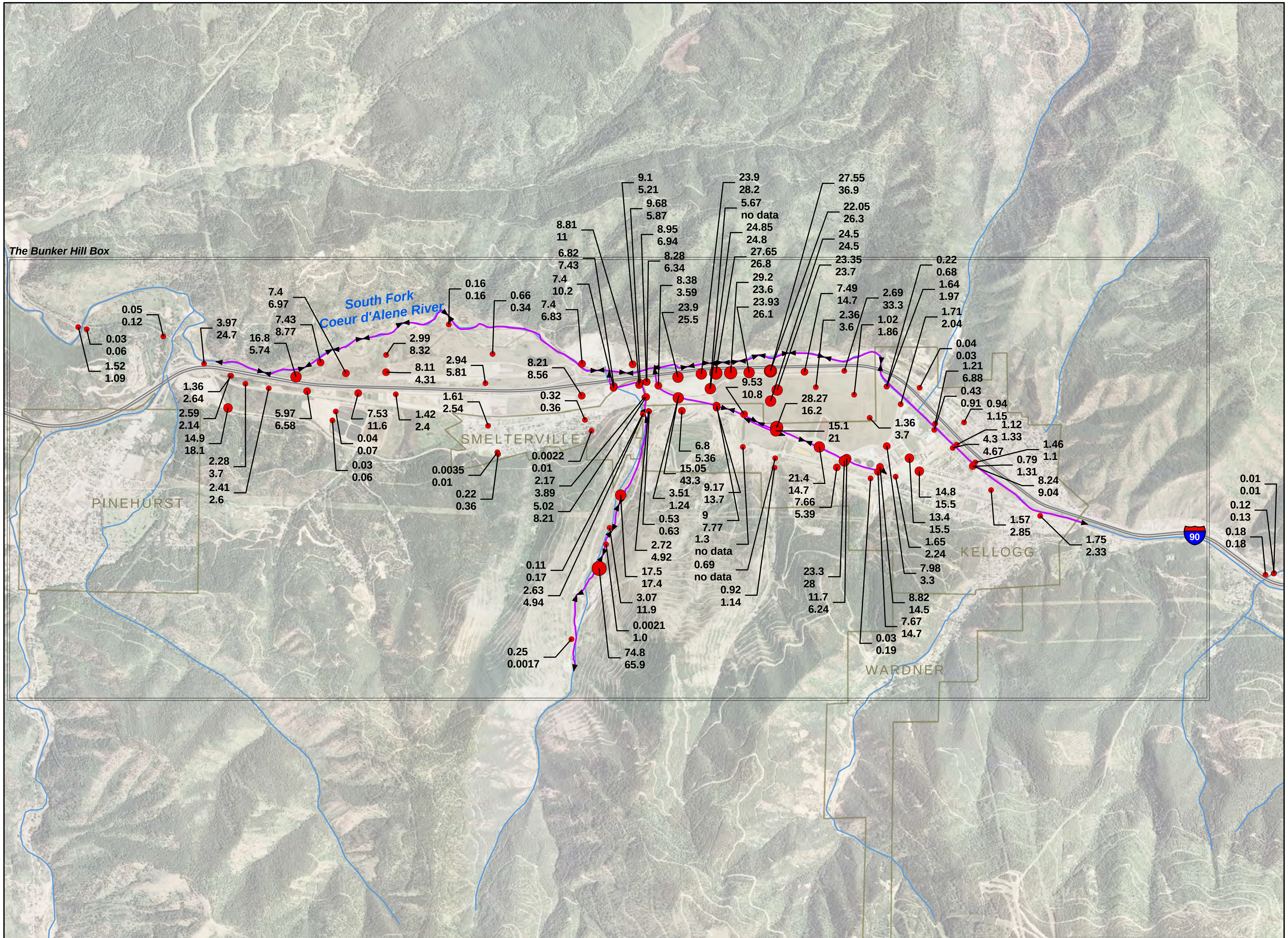
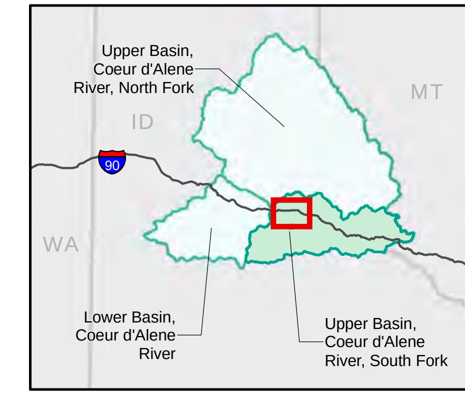


Figure A-14
Simulated versus Measured Groundwater Elevations – Canyon Creek Watershed
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE





Dissolved Zinc (mg/L) (4Q08)

- 0 to 5
- 5 to 10
- 10 to 15
- 15 to 25
- 25 to 50
- 50 to 75
- Mass Loading Reach
- River/Creek
- City Limit

0.12 (4Q08 Dissolved Zinc Concentration [mg/L])
0.13 (2Q09 Dissolved Zinc Concentration [mg/L])
mg/L = milligrams per liter

N
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-15
OU 2 Mass Loading Reaches
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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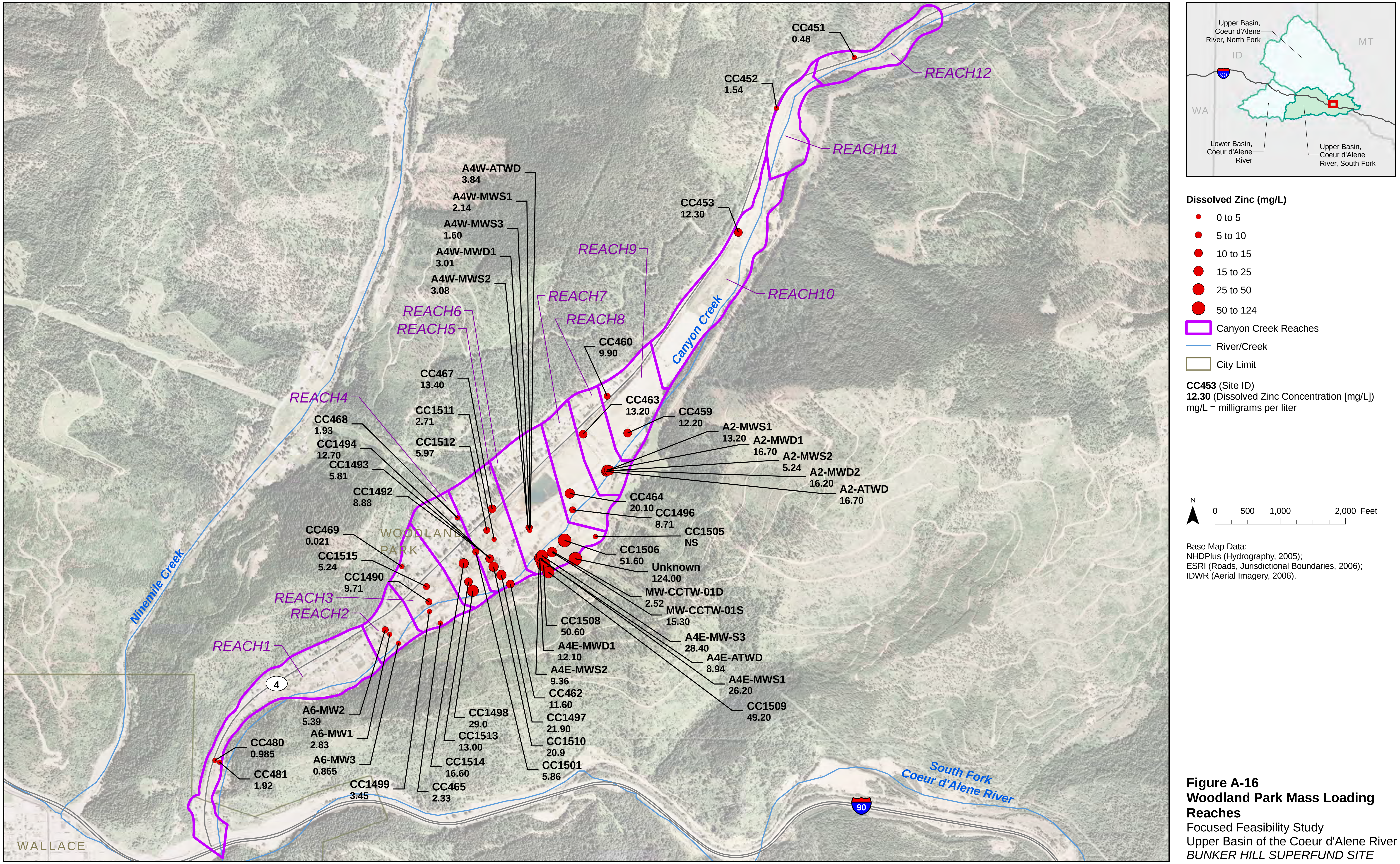

Figure A-16
Woodland Park Mass Loading Reaches

Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA

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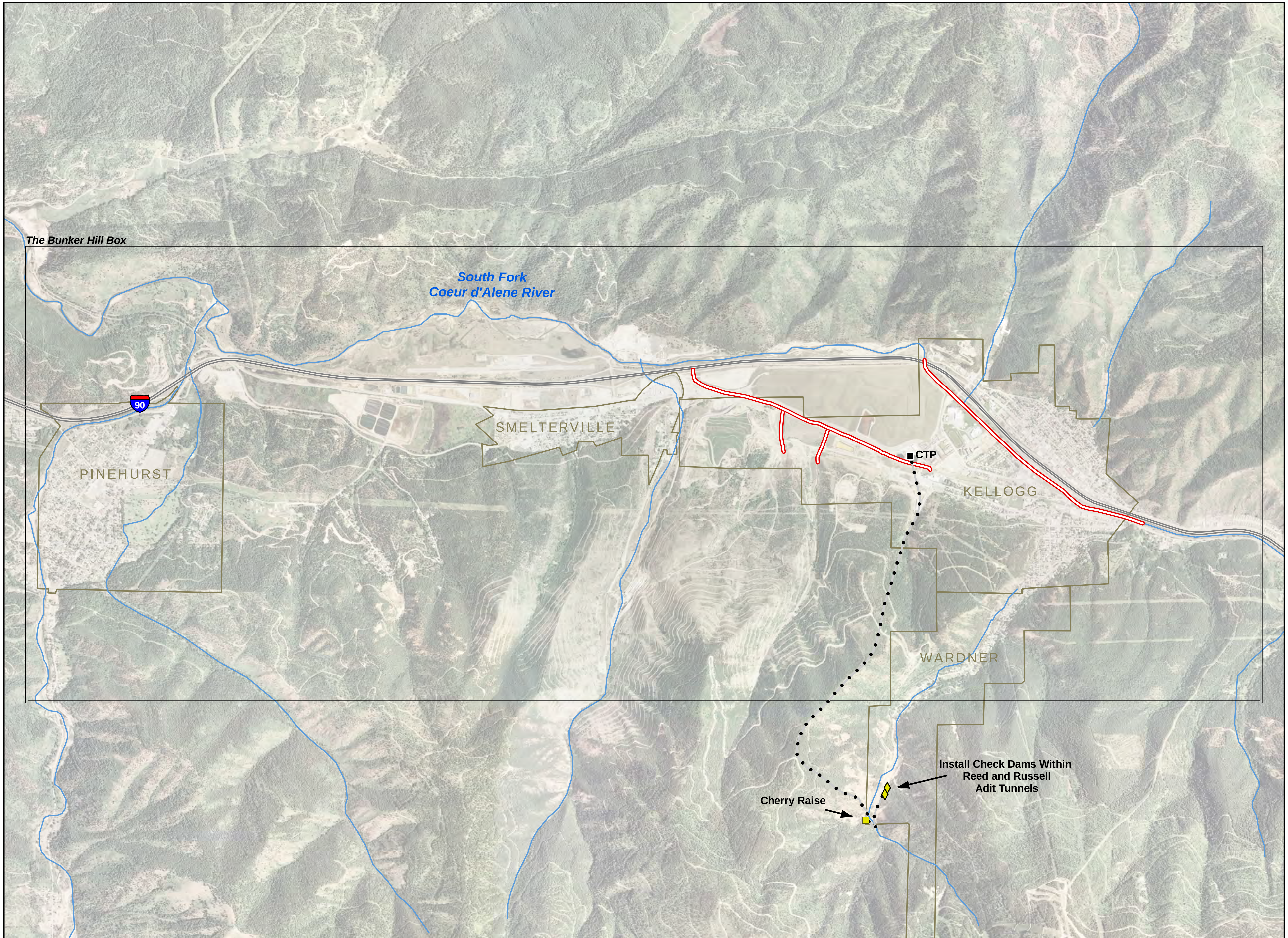

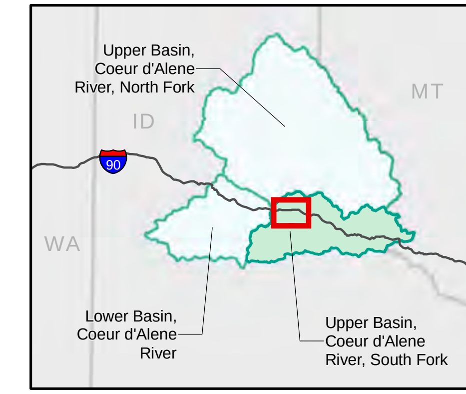

- Central Treatment Plant (CTP)
- Adit
- Raise
- Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP
- Stream Liner
- River/Creek
- City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

N

0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-17
OU 2 Alternative (a):
Minimal Stream Lining
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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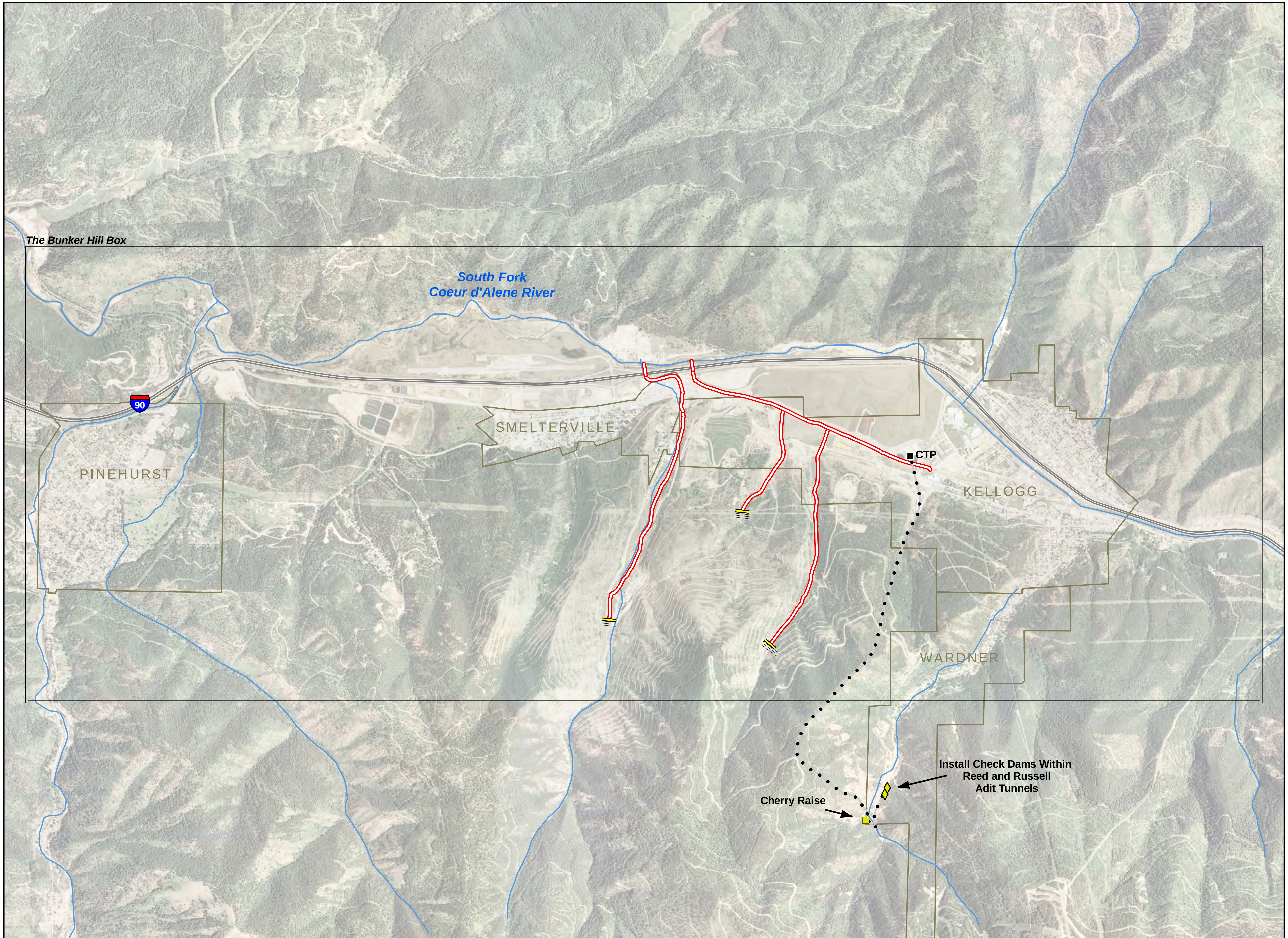
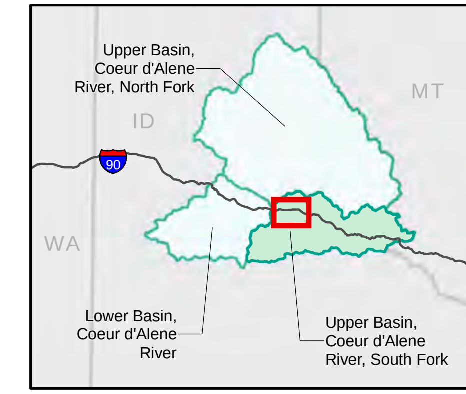




- Central Treatment Plant (CTP)
- Adit
- Raise
- Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP
- Slurry Wall
- Stream Liner
- Extraction Wells
- River/Creek
- City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

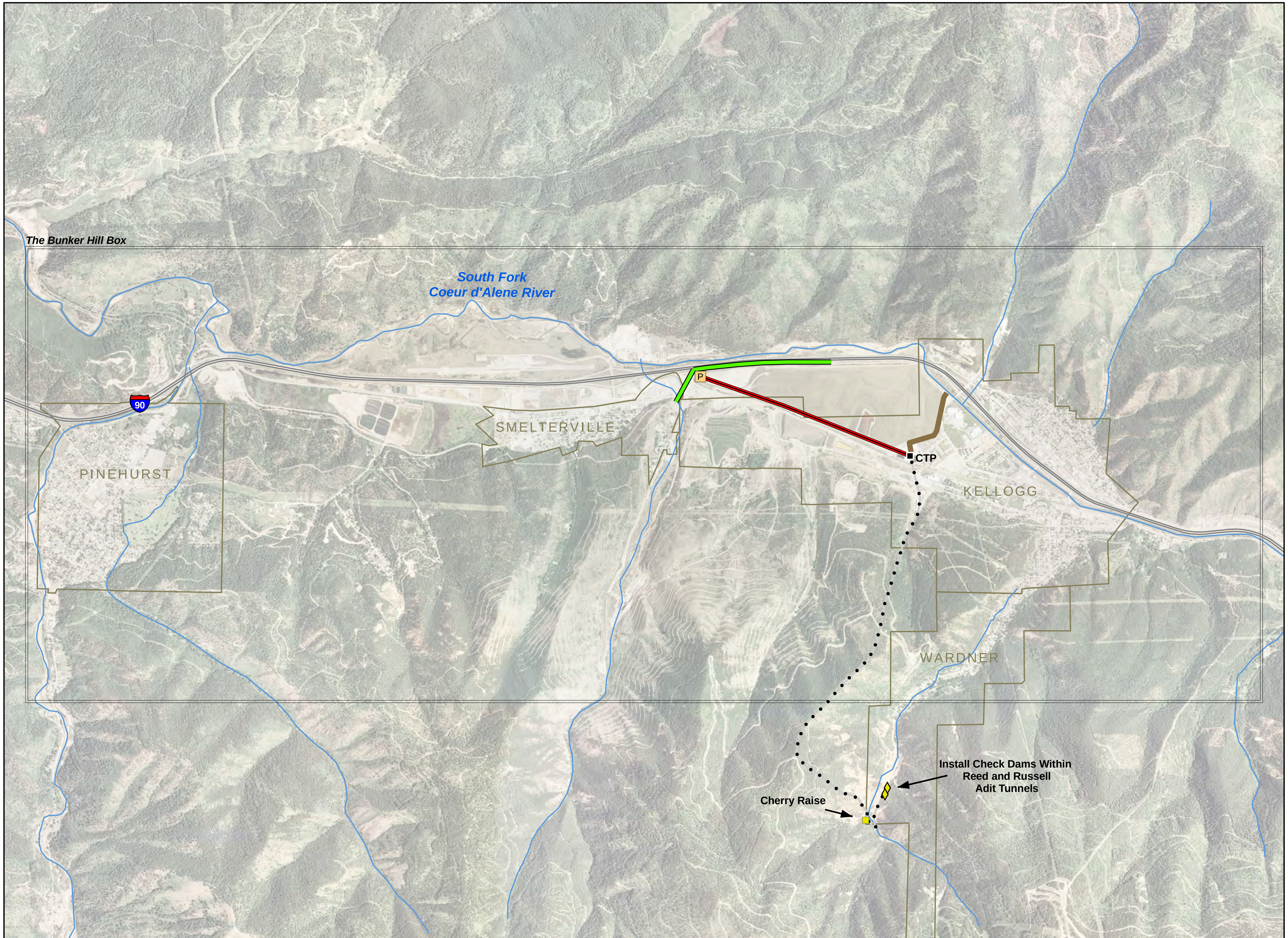
N

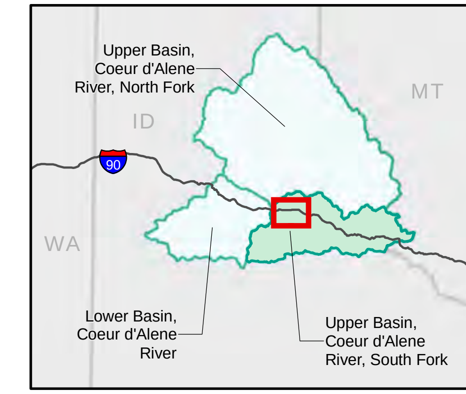
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-18
OU 2 Alternative (b):
Extensive Stream Lining
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA





- Central Treatment Plant (CTP)
- Pump Station
- Adit
- Raise
- Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP
- Conveyance Pipeline
- CTP Effluent Discharge Pipeline
- French Drain
- River/Creek
- City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

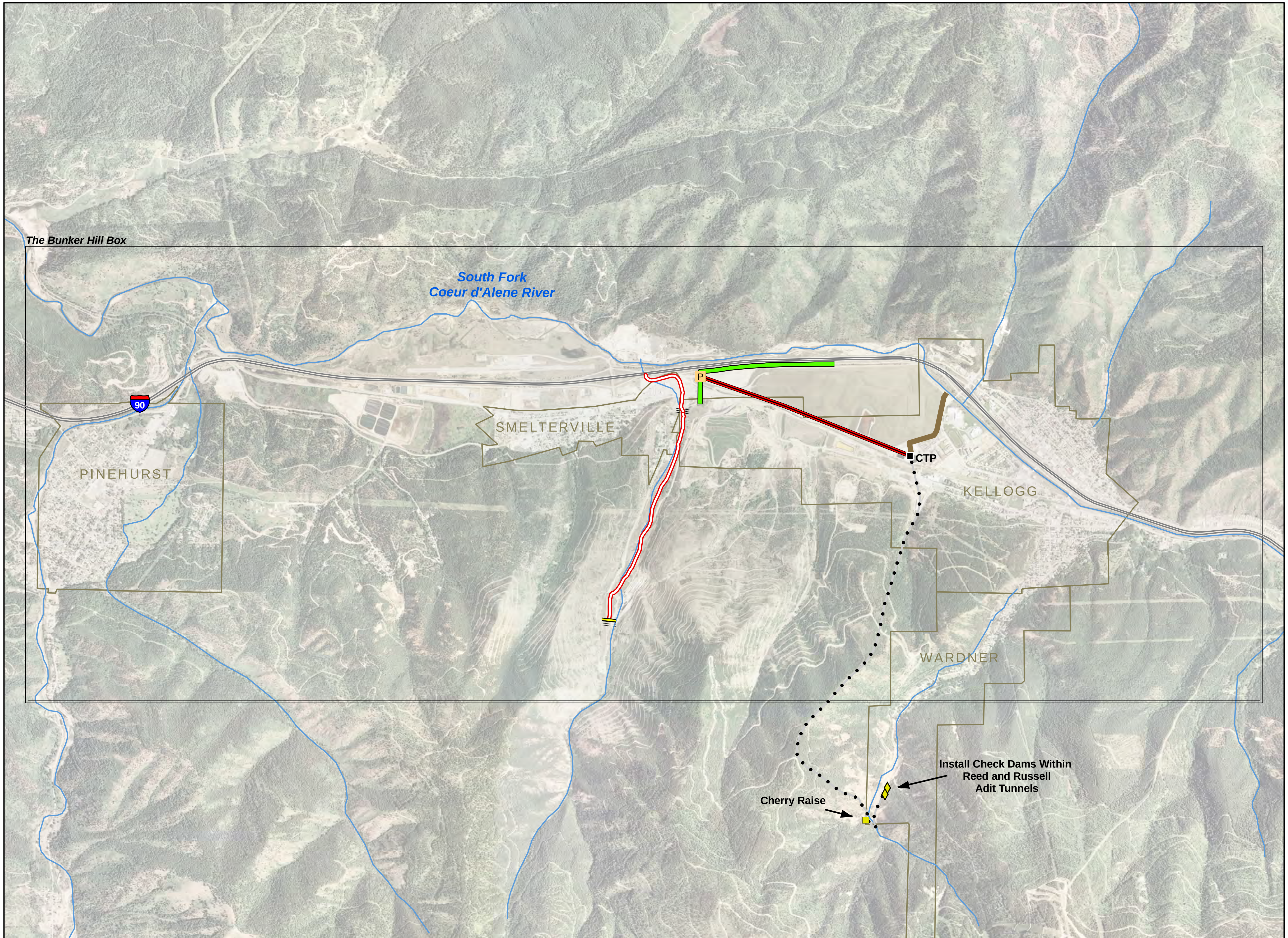
N

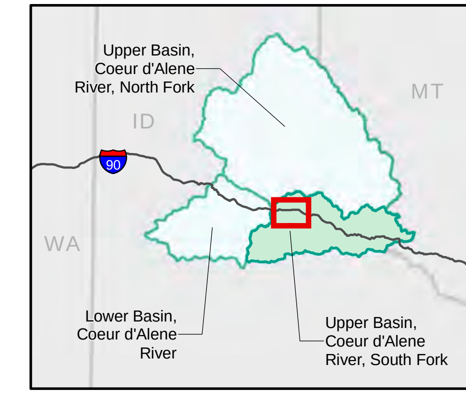
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-19
OU 2 Alternative (c):
French Drains
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA





- Central Treatment Plant (CTP)
- Pump Station
- Adit
- Raise
- Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP
- Conveyance Pipeline
- CTP Effluent Discharge Pipeline
- French Drain
- Slurry Wall
- Stream Liner
- Extraction Wells
- River/Creek
- City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

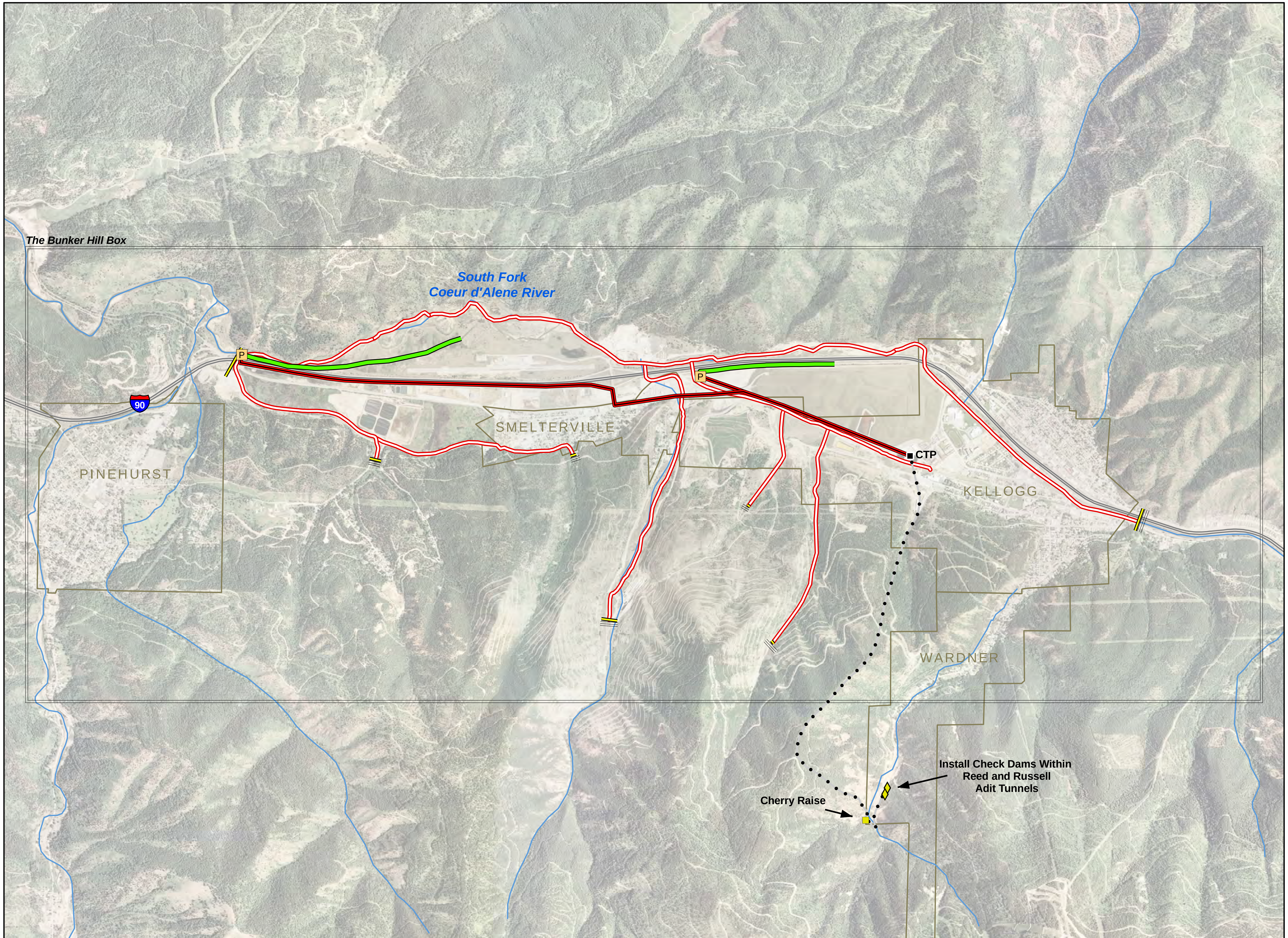
N

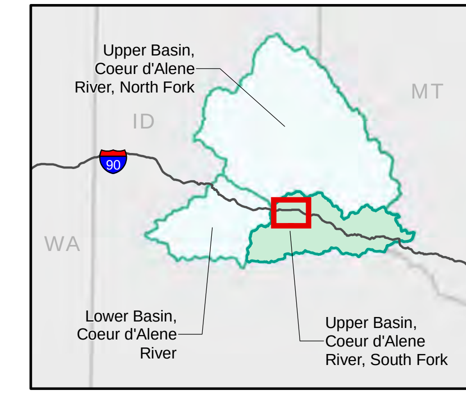
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-20
OU 2 Alternative (d):
Stream Lining/French Drain Combination
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA





- Central Treatment Plant (CTP)
- Pump Station
- Adit
- Raise
- Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP
- Conveyance Pipeline
- French Drain
- Slurry Wall
- Stream Liner
- Extraction Wells
- River/Creek
- City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

N

0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-21
OU 2 Alternative (e):
Extensive Stream Lining/French Drain Combination
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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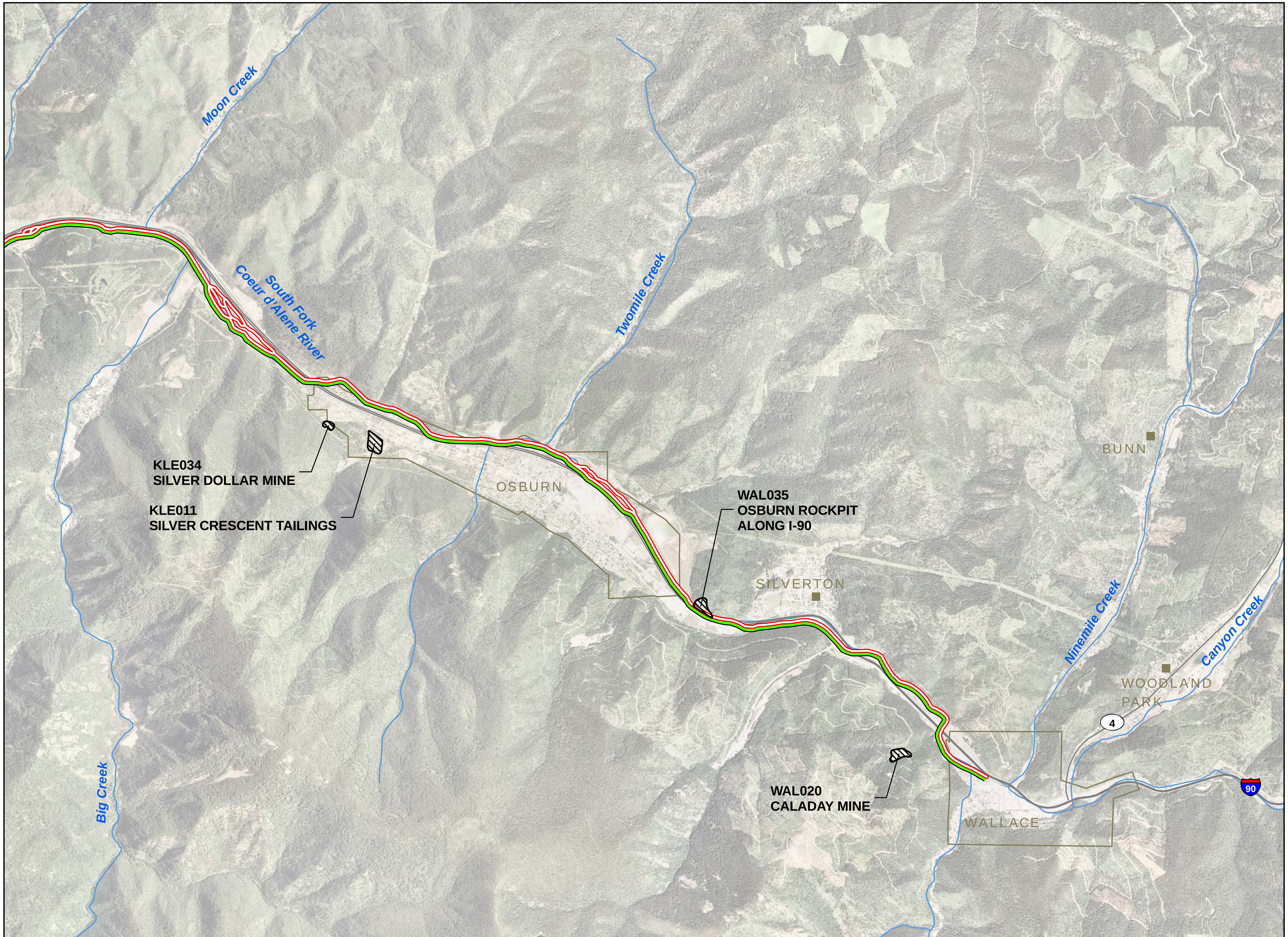
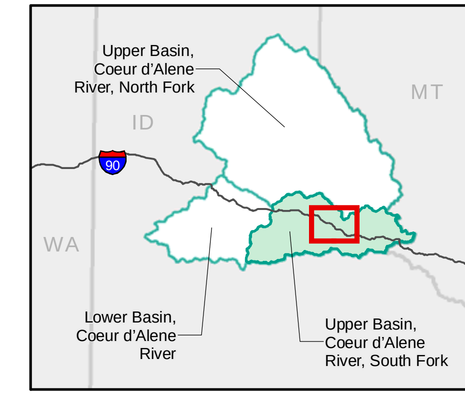




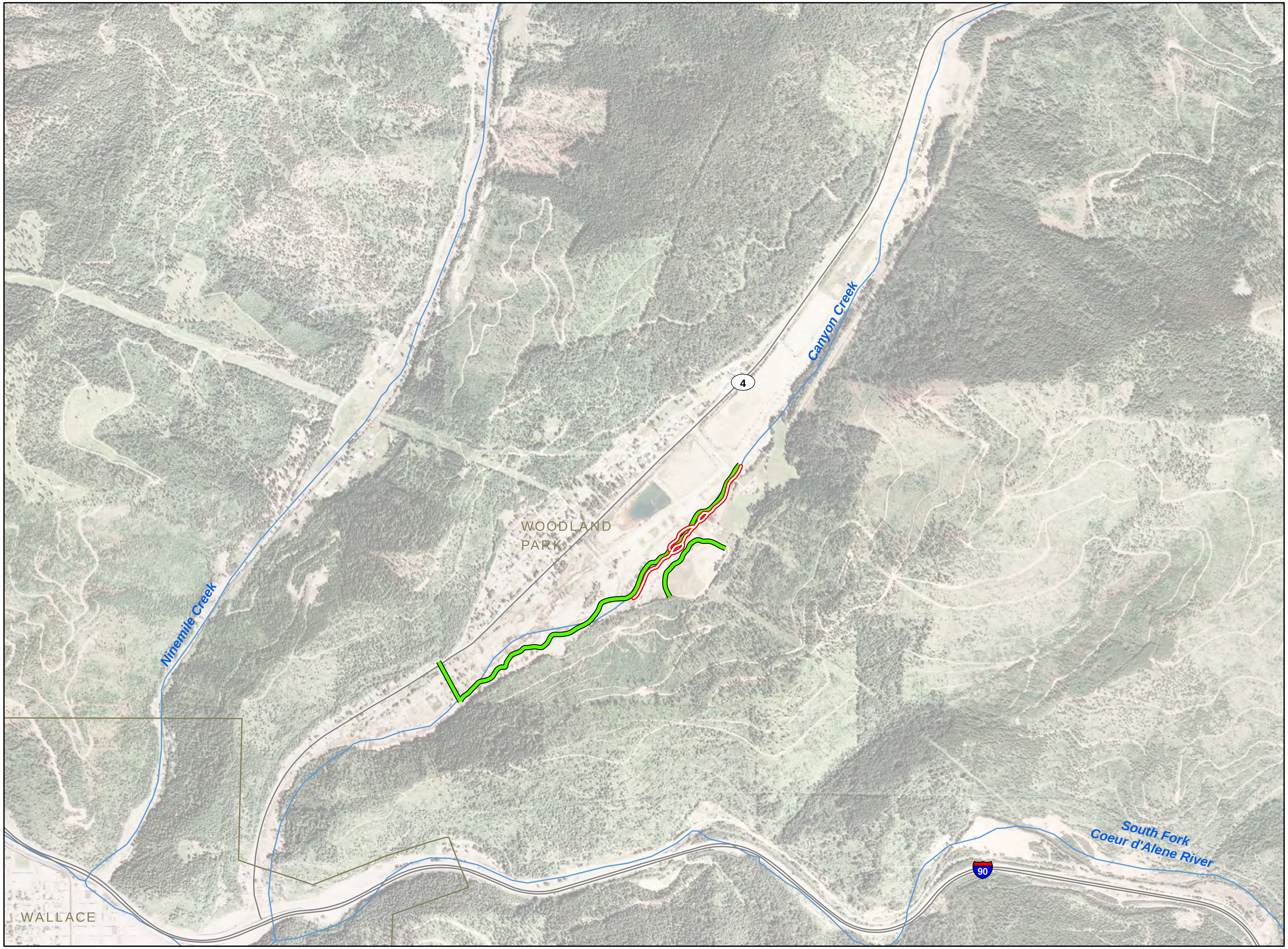
French Drain
Stream Liner
River/Creek
Capped Tailings Pile
City Limit

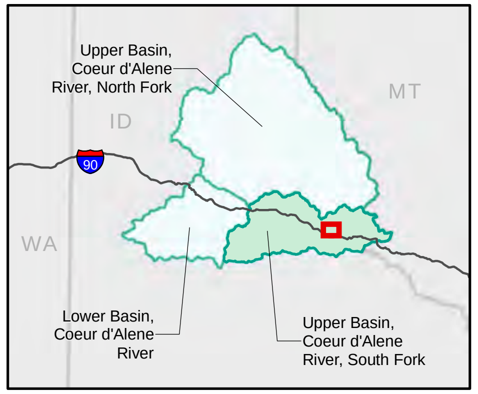
WAL020 (Site ID)
CALADAY MINE (Site Name)

N
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-22
Groundwater Components of OU 3 Remedial Alternatives for the Mainstem SFCDR Watershed, Segment 01
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE





French Drain
Stream Liner
River/Creek
City Limit

N

0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-23
Groundwater Components of Updated Remedial Actions for Woodland Park
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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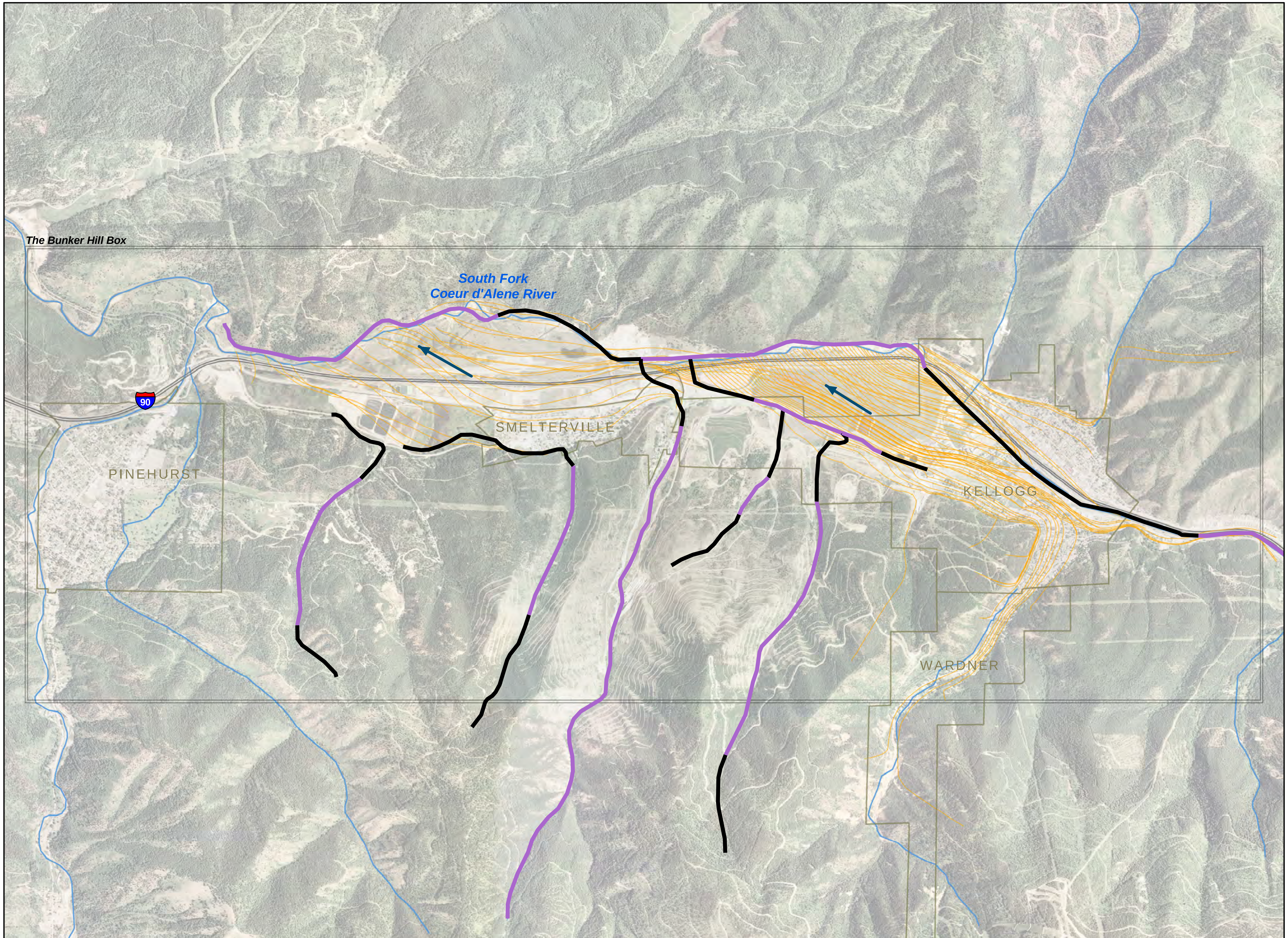

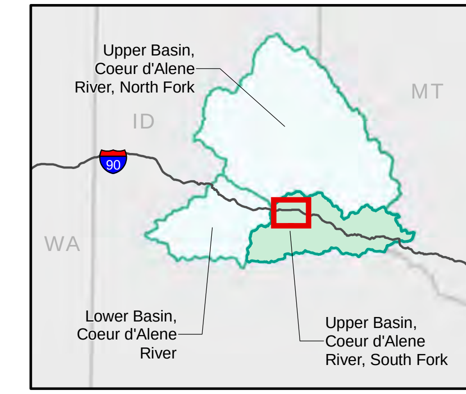

Simulated Groundwater Flowpath
Simulated Gaining Stream Reach
Simulated Losing Stream Reach
Simulated Groundwater Flow Direction
River/Creek
City Limit

N
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-24
Simulated Upstream Groundwater Flowlines from the SFCDR, No Action, Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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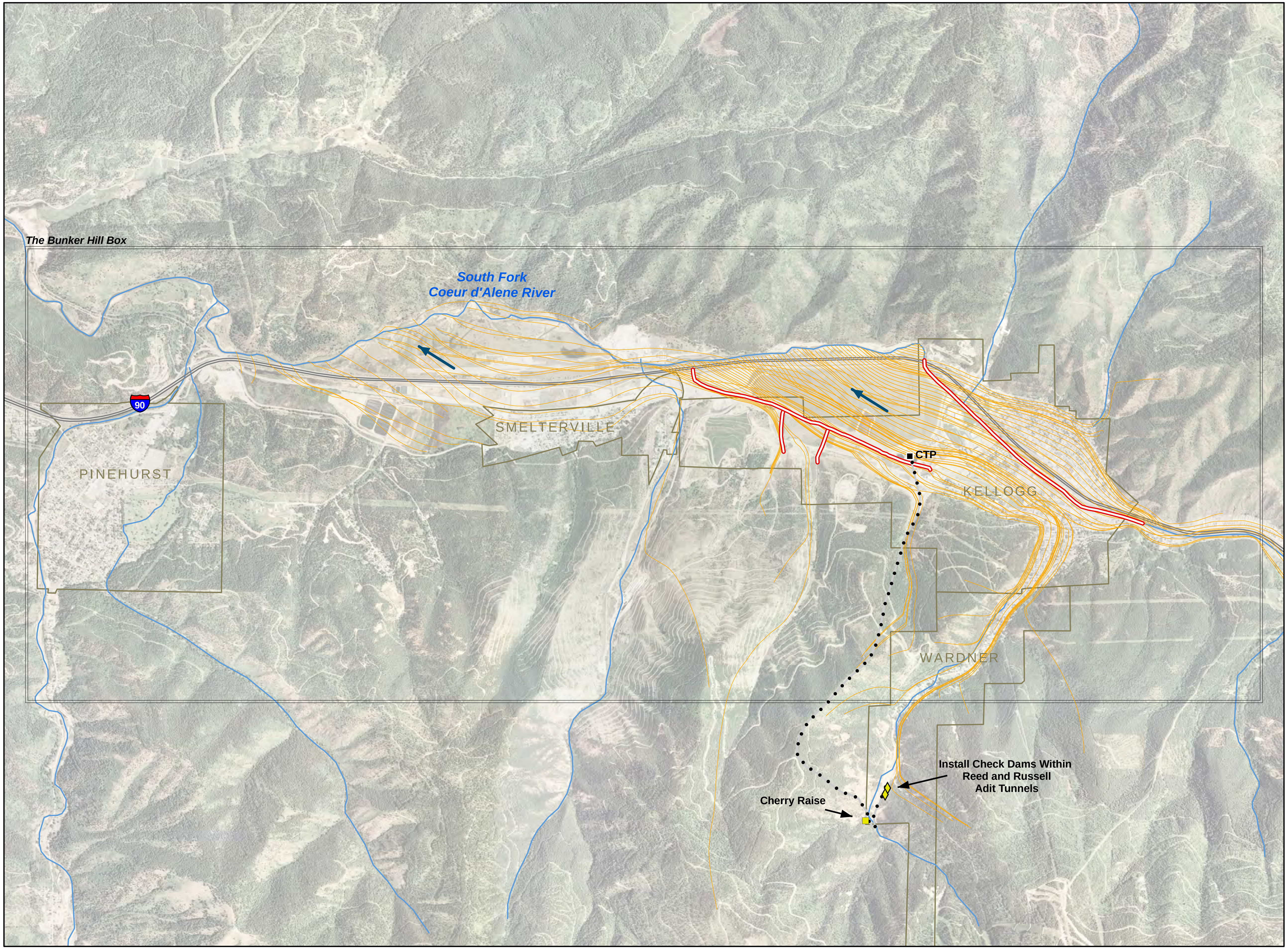
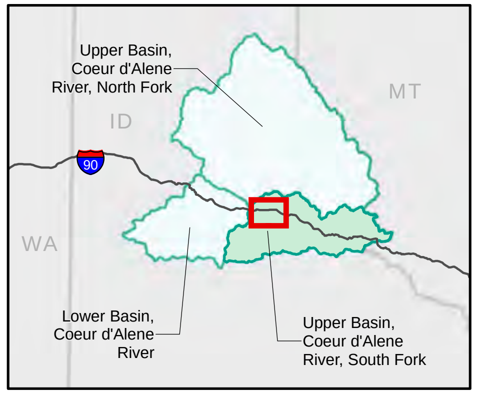




- Central Treatment Plant (CTP)
- Adit
- Raise
- Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP
- Stream Liner
- Simulated Groundwater Flowpath
- Simulated Groundwater Flow Direction
- River/Creek
- City Limit

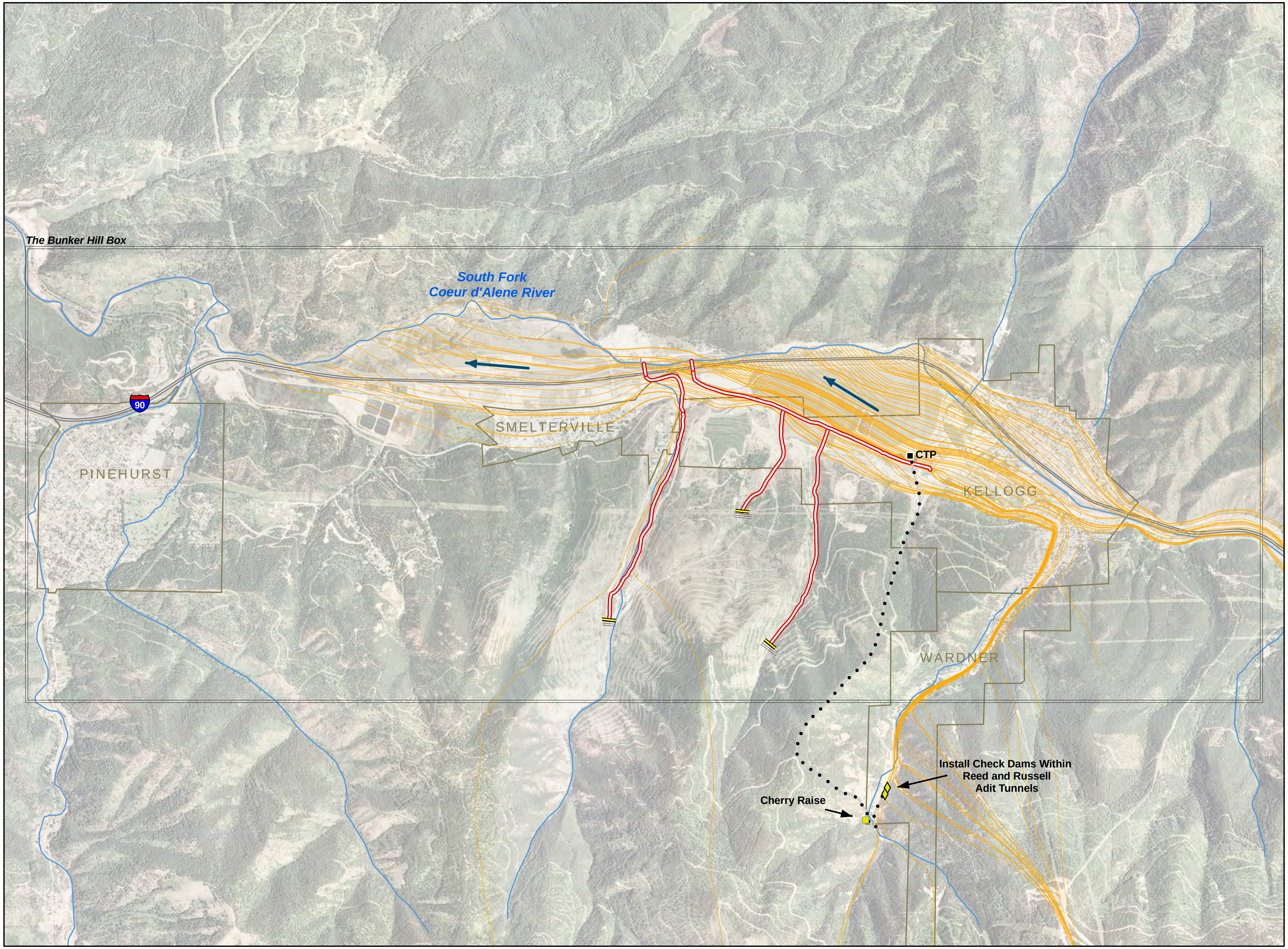
Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

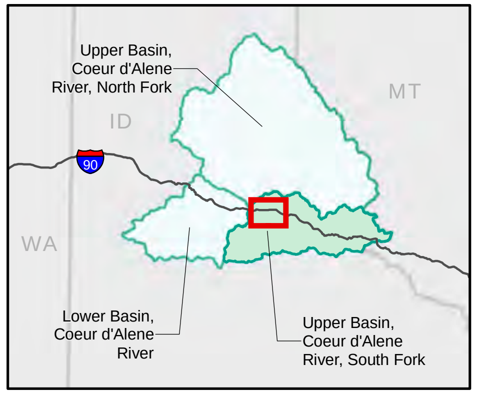
N

0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-25
Simulated Upstream Groundwater Flowlines from the SFCDR, OU 2 Alternative (a), Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE





Central Treatment Plant (CTP)

Adit

Raise

Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP

Slurry Wall

Stream Liner

Extraction Wells

Simulated Groundwater Flowpath

Simulated Groundwater Flow Direction

River/Creek

City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

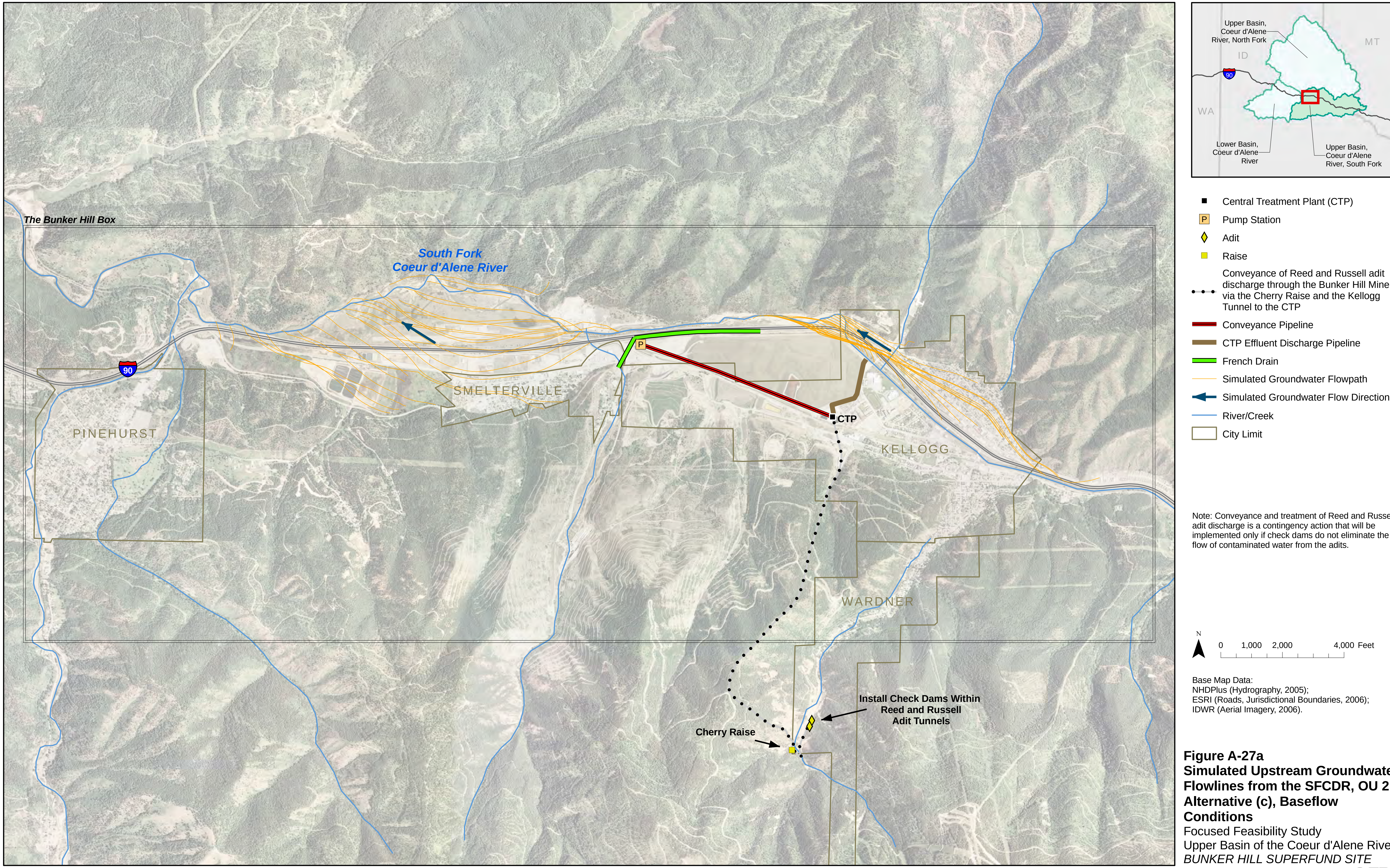
N

0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-26
Simulated Upstream Groundwater Flowlines from the SFCDR, OU 2 Alternative (b), Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

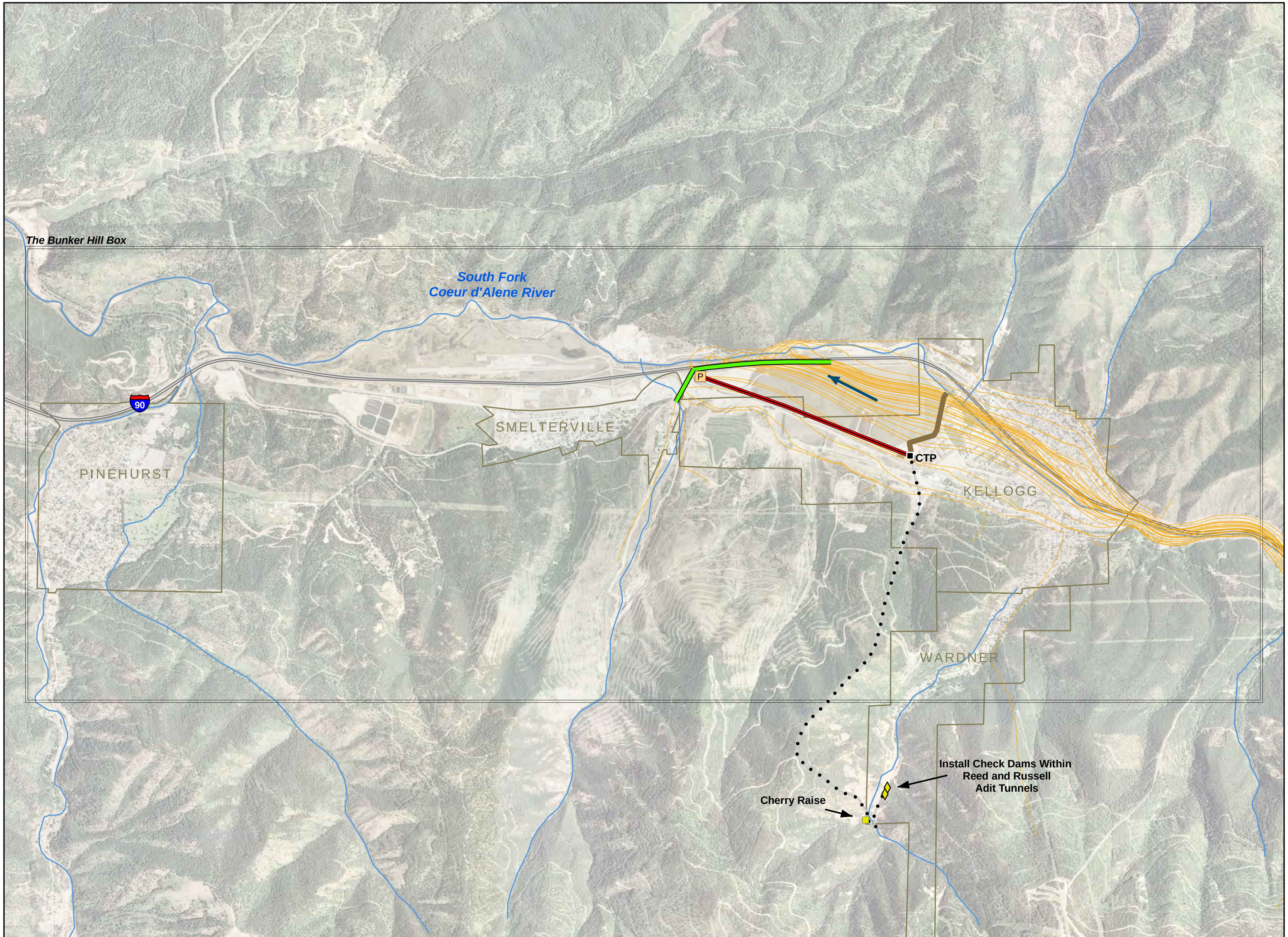
EPA

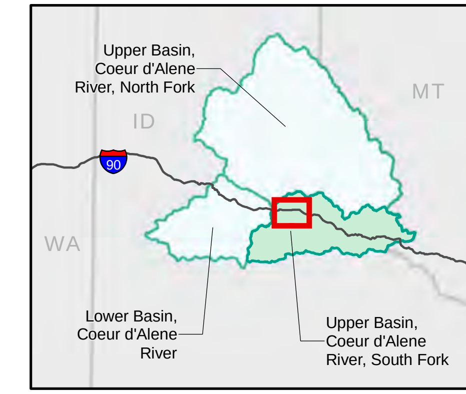


Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-27a
Simulated Upstream Groundwater Flowlines from the SFCDR, OU 2 Alternative (c), Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE





Central Treatment Plant (CTP)

Pump Station

Adit

Raise

Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP

Conveyance Pipeline

CTP Effluent Discharge Pipeline

French Drain

Simulated Groundwater Flowpath

Simulated Groundwater Flow Direction

River/Creek

City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

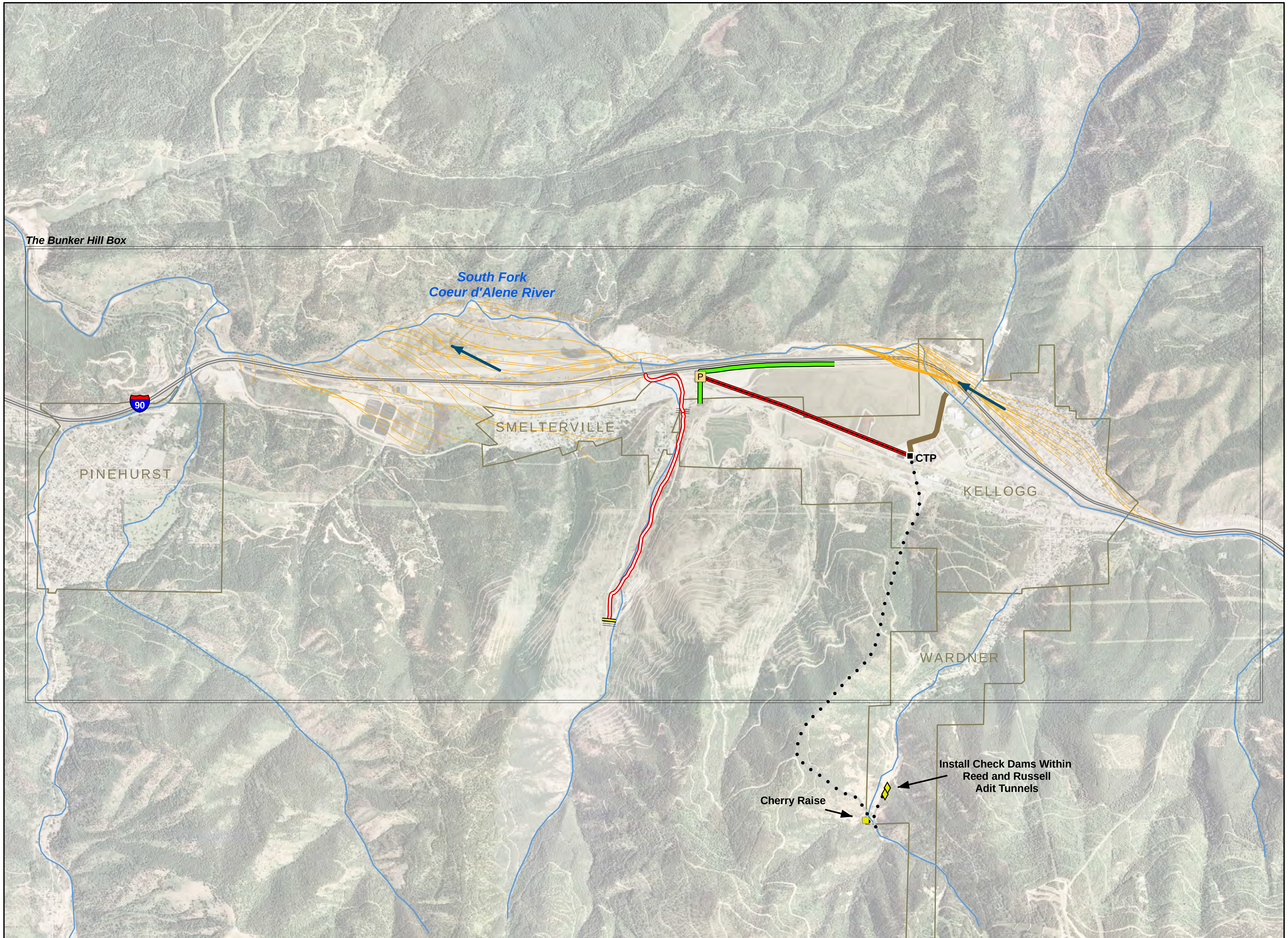
N

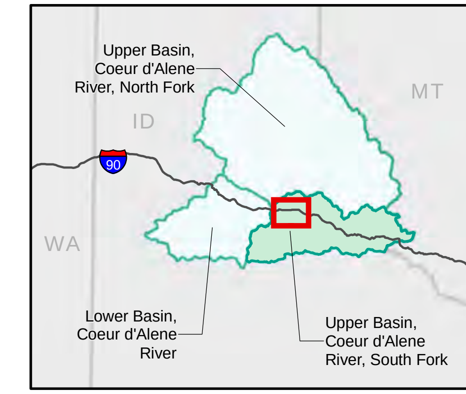
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-27b
Simulated Upstream Groundwater Flowlines from French Drains, OU 2 Alternative (c), Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA





- Central Treatment Plant (CTP)
- Pump Station
- Adit
- Raise
- Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP
- Conveyance Pipeline
- CTP Effluent Discharge Pipeline
- French Drain
- Slurry Wall
- Stream Liner
- Extraction Wells
- Simulated Groundwater Flowpath
- Simulated Groundwater Flow Direction
- River/Creek
- City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

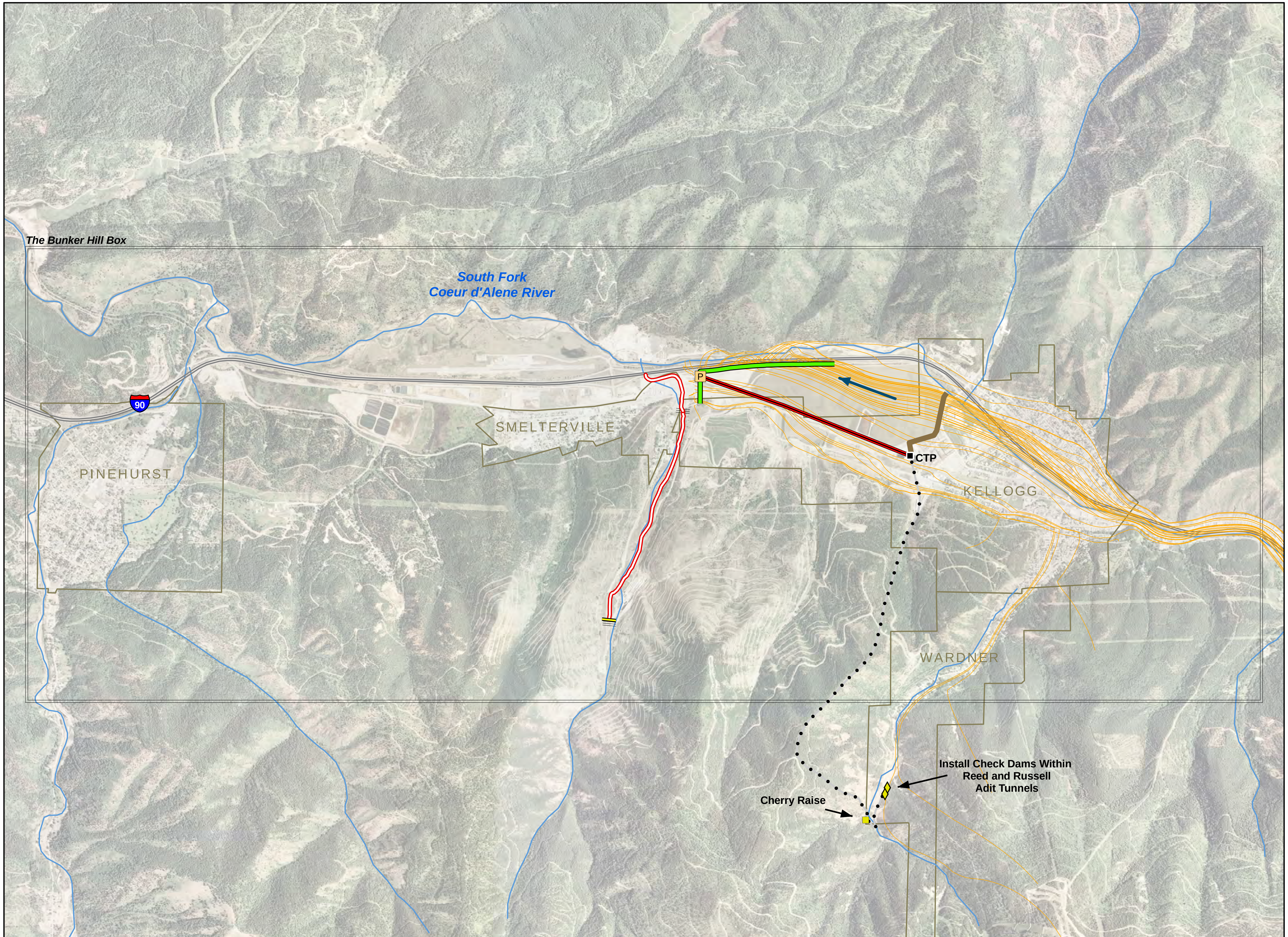
N

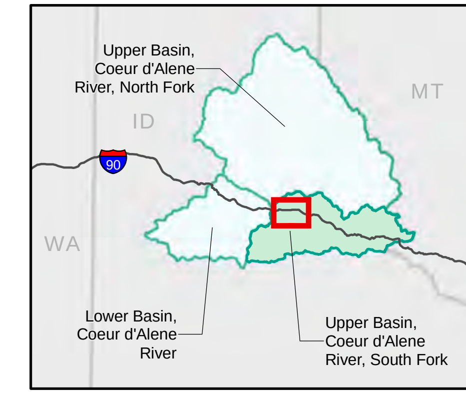
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-28a
Simulated Upstream Groundwater Flowlines from the SFCDR, OU 2 Alternative (d), Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA





Central Treatment Plant (CTP)
Pump Station
Adit
Raise
Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP
Conveyance Pipeline
CTP Effluent Discharge Pipeline
French Drain
Slurry Wall
Stream Liner
Extraction Wells
Simulated Groundwater Flowpath
Simulated Groundwater Flow Direction
River/Creek
City Limit

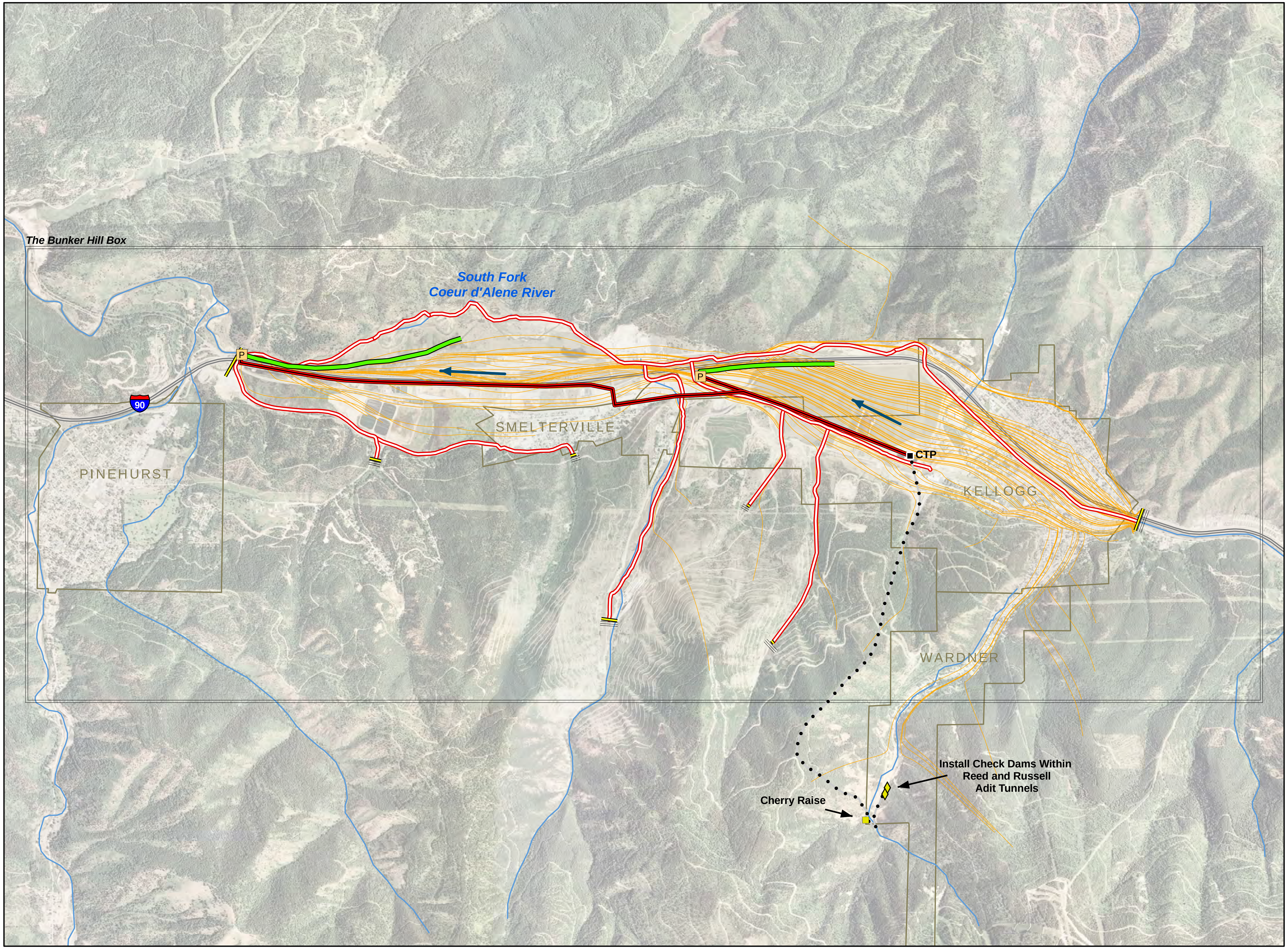
Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

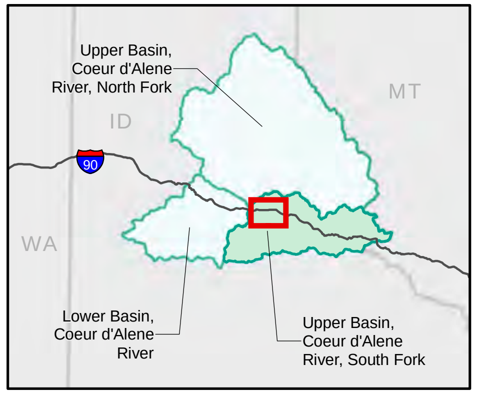
N
0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-28b
Simulated Upstream Groundwater Flowlines from French Drains, OU 2 Alternative (d), Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

EPA





Central Treatment Plant (CTP)

Pump Station

Adit

Raise

Conveyance of Reed and Russell adit discharge through the Bunker Hill Mine via the Cherry Raise and the Kellogg Tunnel to the CTP

Conveyance Pipeline

French Drain

Slurry Wall

Stream Liner

Extraction Wells

Simulated Groundwater Flowpath

Simulated Groundwater Flow Direction

River/Creek

City Limit

Note: Conveyance and treatment of Reed and Russell adit discharge is a contingency action that will be implemented only if check dams do not eliminate the flow of contaminated water from the adits.

N

0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-29
Simulated Upstream Groundwater Flowlines from French Drains, OU 2 Alternative (e), Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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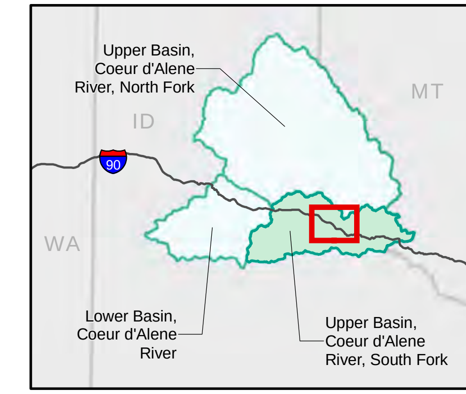


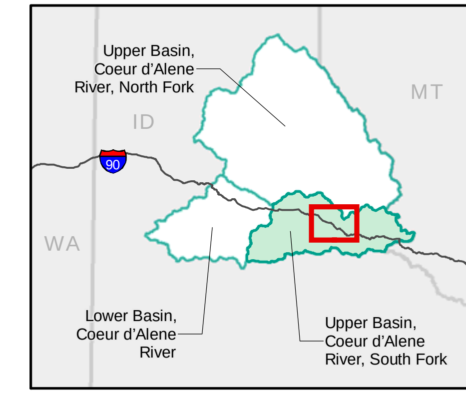
Simulated Groundwater Flowpath
Simulated Groundwater Flow Direction
River/Creek
City Limit

N

0 1,000 2,000 4,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-30
Simulated Upstream Groundwater Flowlines from the SFCDR, Mainstem SFCDR Watershed, Segment 01, No Action, Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE



Simulated Groundwater Flowpath
Simulated Groundwater Flow Direction
French Drain
Stream Liner
River/Creek
Capped Tailings Pile
City Limit

WAL020 (Site ID)
CALADAY MINE (Site Name)

N
0 1,000 2,000 4,000 Feet

Source: NHDPlus (Rivers, Waterbodies); ESRI base data (Interstates 2006, Major Highways 2008); IDWR (Aerial Imagery 2006).

Figure A-31
Simulated Upstream Groundwater Flowlines from French Drains, Mainstem SFCDR Watershed, Segment 01, Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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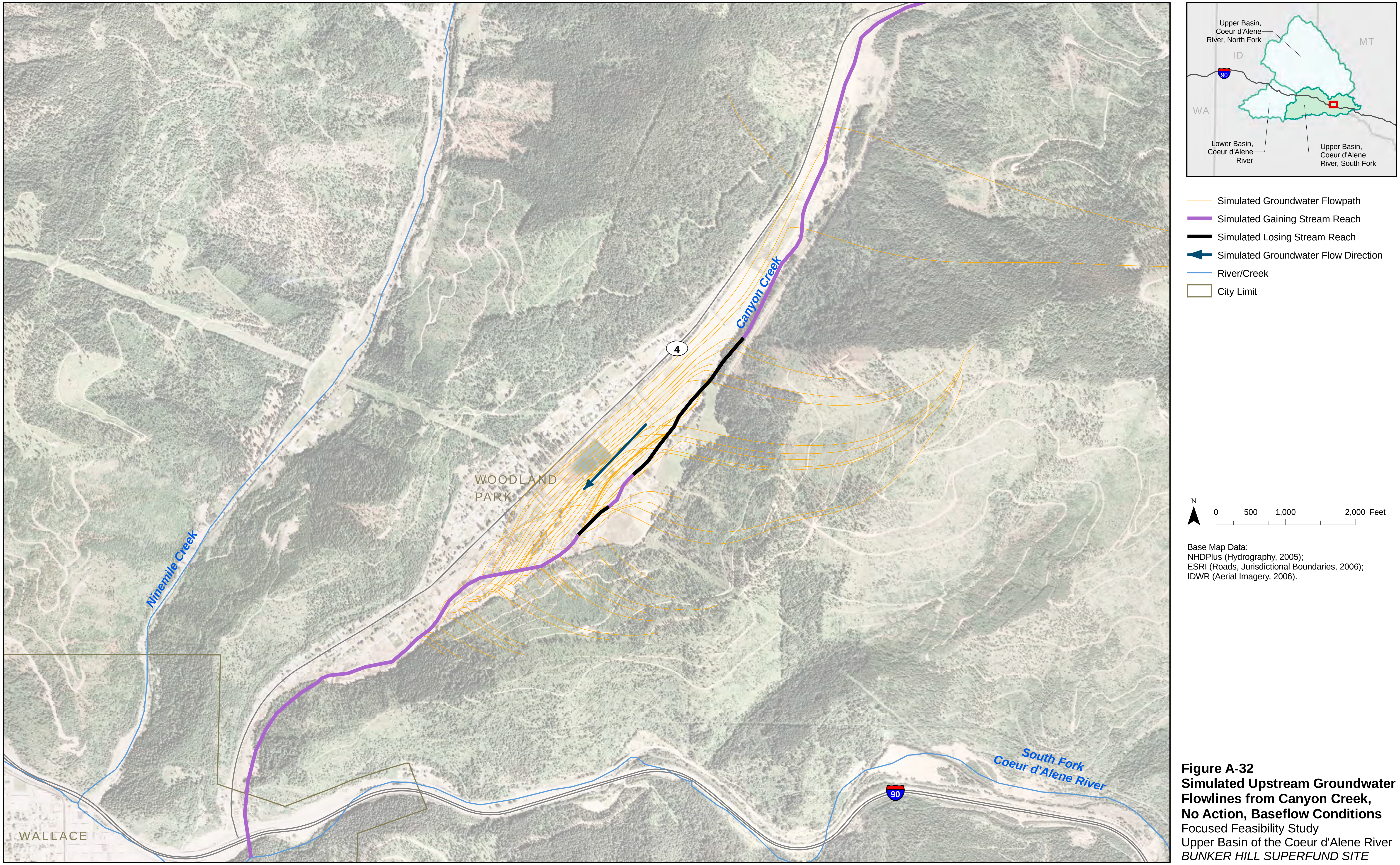

Figure A-32
Simulated Upstream Groundwater Flowlines from Canyon Creek, No Action, Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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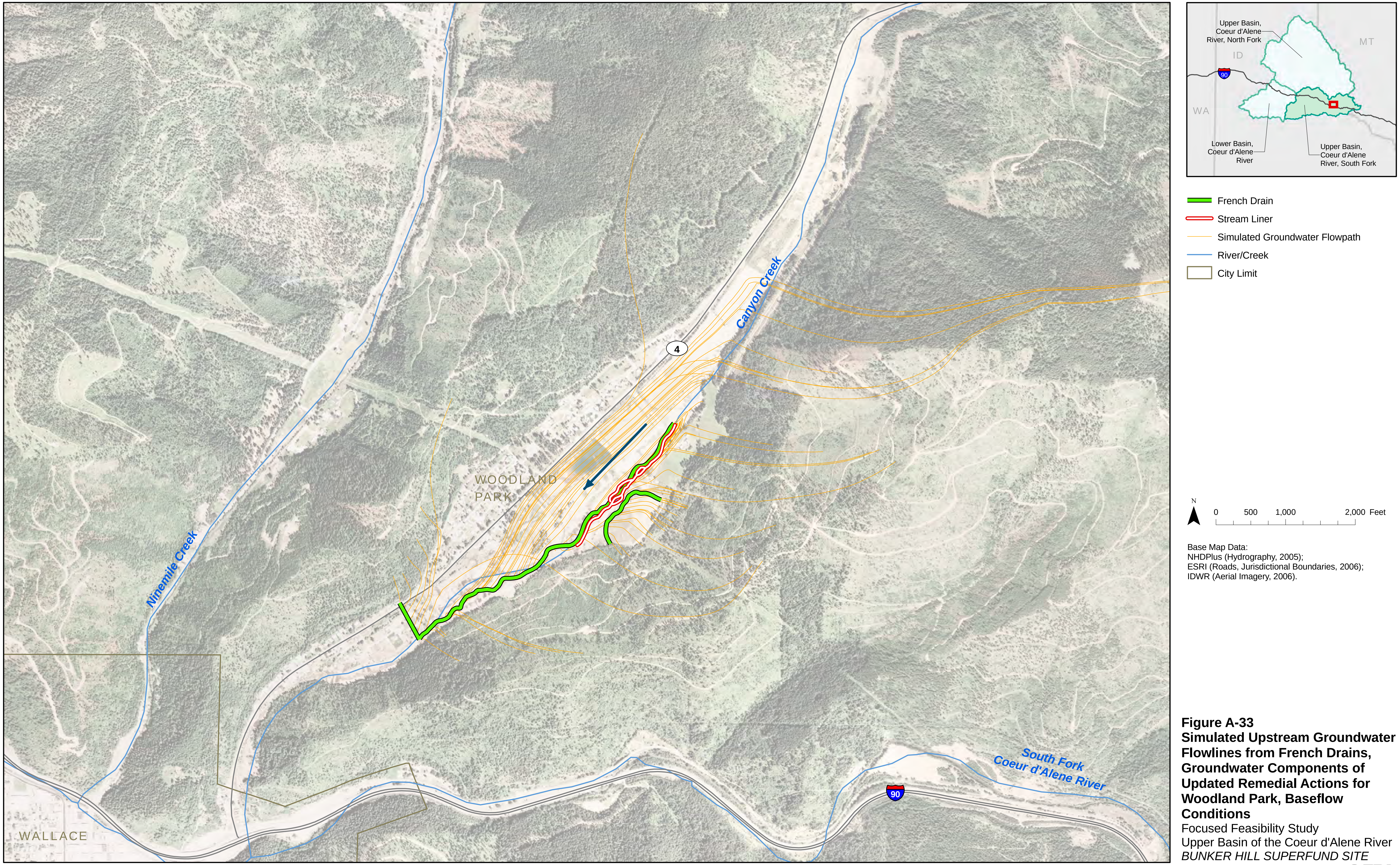

French Drain
Stream Liner
Simulated Groundwater Flowpath
River/Creek
City Limit

N
0 500 1,000 2,000 Feet

Base Map Data:
NHDPlus (Hydrography, 2005);
ESRI (Roads, Jurisdictional Boundaries, 2006);
IDWR (Aerial Imagery, 2006).

Figure A-33
Simulated Upstream Groundwater Flowlines from French Drains, Groundwater Components of Updated Remedial Actions for Woodland Park, Baseflow Conditions
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

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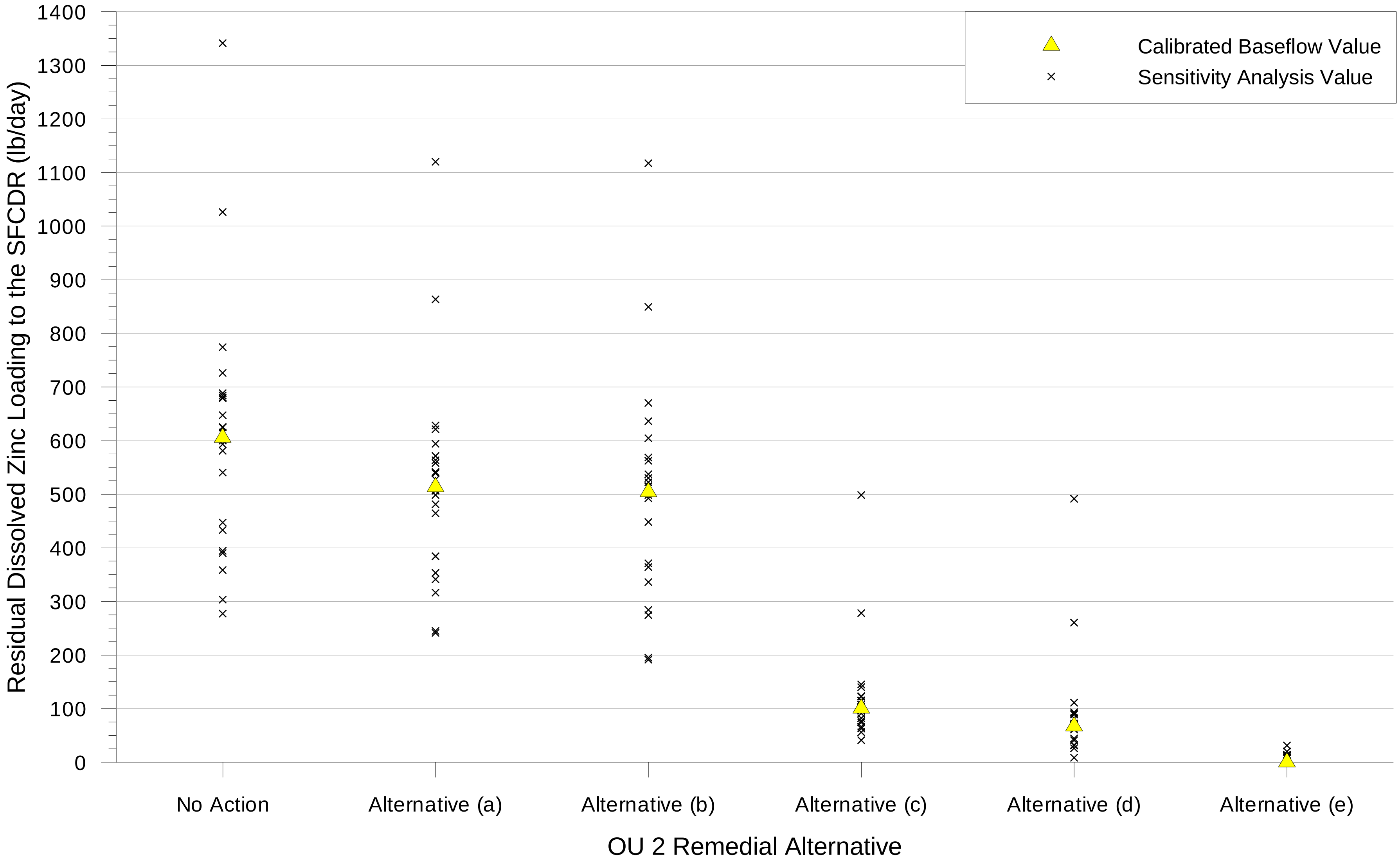

Figure A-34
Results of the OU 2 SensitivityAnalysis
Focused Feasibility Study
Upper Basin of the Coeur d'Alene River
BUNKER HILL SUPERFUND SITE

Notes:
1. lb/day = pounds per day
2. SFCDR = South Fork of the Coeur d'Alene River
3. OU 2 = Operable Unit 2

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Tables

TABLE A-1

Measured Baseflow Groundwater and Surface Water Elevations in Monitoring Pairs – Government Gulch

Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Monitoring Well and Stream Gauging Station Pair	Fall 2007 Elevations (feet msl)	Elevation Difference (feet)	Fall 2007 Discharge (ft^3/s)	Fall 2008 Elevations (feet msl)	Elevation Difference (feet)	Fall 2008 Discharge (cfs)
BH-GG-GW-0002	2605.455			2605.645		
BH-GG-0002	2604.582	0.873	0.83	2604.622	1.023	1.18
BH-GG-GW-0009	2475.735			2475.615		
BH-GG-0005	2476.726	-0.991	2.41	NM		NM
BH-GG-GW-0010	2440.778			2440.498		
BH-GG-0006	2436.515	4.263	1.24	2436.465	4.033	1.52
BH-GG-GW-0003	2407.657			2407.427		
BH-GG-0007	2409.55	-1.893	1.25	2409.57	-2.143	0.99
BH-GG-GW-0004	2362.222			2362.062		
BH-GG-0008	2363.702	-1.48	1.38	2363.742	-1.68	1.29
BH-GG-GW-0005	2243.52			2243.58		
BH-GG-GW-0007	2239.8			2239.91		
BH-GG-0001	NM		NM	2253.339	-11.594	1.45

Notes:

Monitoring pairs listed from upstream to downstream.
A positive elevation difference indicates an upward hydraulic gradient (gaining stream).
Surface water and groundwater measurements not collected on the same date.
NM = not measured
msl = mean sea level
cfs = cubic feet per second

TABLE A-2
Final PEST Parameter Multipliers
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Parameter	Multiplier
Horizontal Hydraulic Conductivity - Layer 1 Alluvium	1.04
Horizontal Hydraulic Conductivity - Layer 1 Bedrock	1.00
Vertical Hydraulic Conductivity - Layer 1 Alluvium	1.00
Vertical Hydraulic Conductivity - Layer 1 Bedrock	1.00
Horizontal Hydraulic Conductivity - Layer 2 Alluvium	0.49
Horizontal Hydraulic Conductivity - Layer 2 Bedrock	1.00
Vertical Hydraulic Conductivity - Layer 2 Alluvium	1.00
Vertical Hydraulic Conductivity - Layer 2 Bedrock	1.00
Horizontal Hydraulic Conductivity - Layer 3 Alluvium	5.53
Horizontal Hydraulic Conductivity - Layer 3 Bedrock	1.00
Vertical Hydraulic Conductivity - Layer 3 Alluvium	1.00
Vertical Hydraulic Conductivity - Layer 3 Bedrock	1.00
Horizontal Hydraulic Conductivity - Layer 4 Alluvium	0.66
Horizontal Hydraulic Conductivity - Layer 4 Bedrock	1.00
Vertical Hydraulic Conductivity - Layer 4 Bedrock	1.00
Wadi Conductance - Osburn Flats Reach 1	0.26
Wadi Conductance - Osburn Flats Reach 2	0.60
Wadi Conductance - Osburn Flats Reach 3	1.14
Wadi Conductance - Osburn Flats Reach 4	0.88
Wadi Conductance - Bunker Hill Box Reach 1	0.30
Wadi Conductance - Bunker Hill Box Reach 2	2.14
Wadi Conductance - Bunker Hill Box Reach 3	0.79
Wadi Conductance - Bunker Hill Box Reach 4	0.84
Wadi Conductance - Bunker Hill Box Reach 5	1.00

Note:

PEST = parameter estimation

TABLE A-3
Simulated versus Observed Vertical Head Gradients in Well Pairs – Bunker Hill Box
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Well Name	Difference in Well Screen Mid-Points (feet)	Observed Groundwater Elevation (feet msl)	Observed Vertical Gradient (ft/ft)	Simulated Groundwater Elevation Previous Calibration (feet msl)	Simulated Vertical Gradient Previous Calibration (ft/ft)	Simulated Groundwater Elevation Updated Calibration (feet msl)	Simulated Vertical Gradient Updated Calibration (ft/ft)
BH-SF-E-0002	35	2,341.60	0.012	2,340.03	0.002	2,339.71	0.003
BH-SF-E-0003		2,341.10		2,339.94		2,339.60	
BH-SF-E-PZ-03	50.5	2,283.40	0.315	2,287.15	0.08	2,288.30	0.05
BH-SF-E-0104		2,267.50		2,283.11		2,285.95	
BH-SF-E-0202-U	50.5	2,275.80	0.175	2,277.97	0.042	2,279.11	0.03
BH-SF-E-0203-L		2,267.00		2,275.87		2,277.63	
BH-SF-E-0301-U	53	2,268.30	0.059	2,271.41	0.028	2,273.45	0.04
BH-SF-E-0302-L		2,265.20		2,269.92		2,271.54	
BH-SF-E-0306-U	42.5	2,266.20	0.014	2,270.25	0.007	2,271.85	0.008
BH-SF-E-0305-L		2,265.60		2,269.95		2,271.50	
BH-SF-E-0309-U	45.5	2,272.40	0.133	2,271.06	0.02	2,271.86	0.008
BH-SF-E-0310-L		2,266.40		2,270.16		2,271.50	
BH-SF-E-0314-U	6	2,269.70	0.027	2,268.49	0.037	2,268.88	0.006
BH-SF-E-0315-U		2,269.60		2,268.27		2,268.84	
BH-SF-E-0423-U	62	2,243.50	-0.021	2,246.01	-0.079	2,246.87	-0.09
BH-SF-E-0424-L		2,244.80		2,250.91		2,252.25	
BH-SF-E-0425-U	51	2,243.10	0.027	2,246.00	-0.049	2,246.70	-0.06
BH-SF-E-0426-L		2,241.70		2,248.52		2,249.62	
BH-SF-E-0427-U	58.5	2,246.60	0.1	2,248.31	-0.026	2,248.73	-0.04
BH-SF-E-0428-L		2,240.70		2,249.85		2,250.93	
BH-SF-W-0003-U	66.5	2,214.40	-0.014	2,219.39	0.013	2,219.82	0.015
BH-SF-W-0004-L		2,215.40		2,218.53		2,218.83	
BH-SF-W-0005-U	75	2,215.60	-0.037	2,217.72	0.01	2,218.22	0.011
BH-SF-W-0006-L		,2218.4		2,216.98		2,217.43	
BH-SF-W-0010-U	59	2,210.20	0.012	2,208.91	-0.01	2,209.97	-0.006
BH-SF-W-0011-L		2,209.50		2,209.51		2,210.32	
BH-SF-W-0121-U	72.5	2,188.80	-0.077	2,188.57	-0.002	2,188.74	-0.005
BH-SF-W-0122-L		2,194.40		2,188.71		2,189.08	
BH-SF-W-0201-U	92.5	2,187.00	-0.042	2,186.12	0.001	2,186.46	-0.001
BH-SF-W-0202-L		2,190.90		2,186.07		2,186.55	
BH-SF-W-0204-U	100.5	2,172.90	0.011	2,171.25	0.008	2,171.65	0.009
BH-SF-W-0205-L		2,171.80		2,170.44		2,170.71	
BH-SF-W-0206-U	119	2,171.70	0.006	2,170.07	0.008	2170.496	0.009
BH-SF-W-0207-L		2,171.00		2,169.17		2169.404	

Notes:
A positive value indicates a downward vertical gradient.
ft/ft = foot per foot
msl = mean sea level

TABLE A-4
Simulated versus Observed Vertical Head Gradients in Well Pairs – Osburn Flats
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Well Name	Difference in Well Screen Mid-Points (feet)	Observed Groundwater Elevation (feet msl)	Observed Vertical Gradient (ft/ft)	Simulated Groundwater Elevation Previous Calibration (feet msl)	Simulated Vertical Gradient Previous Calibration (ft/ft)	Simulated Groundwater Elevation Updated Calibration (feet msl)	Simulated Vertical Gradient Updated Calibration (ft/ft)
SF-OB-MW-01S	9.6	2,547.80	0.055	2,543.70	-0.005	2,543.82	0.007
SF-OB-MW-01D		2,547.20		2,543.80		2,543.76	
SF-OB-PZ-17	11.3	2,499.50	0.304	2,500.50	-0.067	2,501.13	-0.162
SF-OB-MW-02		2,496.10		2,501.30		2,502.96	
SF-OB-PZ-24	17.8	2,451.90	0.041	2,451.80	-0.023	2,453.92	-0.008
SF-OB-MW-03		2,451.10		2,452.30		2,454.06	
SF-OB-MW-06	1.8	2,503.20	-0.003	2,505.30	0.12	2,506.29	0.102
SF-OB-PZ-16		2,503.20		2,505.10		2,506.10	
SF-OB-PZ-14	15.4	2,504.50	0.023	2,504.90	0.002	2,505.85	-0.006
SF-OB-MW-07		2,504.20		2,504.90		2,505.93	
SF-OB-PZ-13	8.1	2,511.30	0.028	2,511.70	-0.042	2,511.77	-0.039
SF-OB-MW-09		2,511.10		2,512.00		2,512.08	
SF-OB-PZ-23	5.4	2,452.90	0.015	2,455.10	0.03	2,457.99	0.024
SF-OB-MW-11		2,452.80		2,455.00		2,457.86	

Notes:

A positive value indicates a downward vertical gradient.
ft/ft = foot per foot
msl = mean sea level

TABLE A-5

Comparison of Simulated Stream Gains and Losses to Data Measured During the 2008 Groundwater-Surface Water Interaction Studies

Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

		SFCDR Discharge Gain/Loss (cfs)					
SFCDR Reaches[a]	**Gain/Loss Condition**	**9/23/2008**	**9/24/2008**	**9/25/2008**	**3-day Average**	**Model-simulated Previous Calibration**	**Model-simulated Previous Calibration**
BH-SF-LF-0001 to BH-SF-LF-0003	Losing	-6	-10	-7	-7.7	-2.7	-1.8
BH-SF-LF-0003 to BH-SF-LF-0006	Gaining	5	-1	6	3.3	4.8	4.5
BH-SF-LF-0006 to BH-SF-LF-0008	Losing	-5	3	-11	-4.3	-0.4	0.1
BH-SF-LF-0008 to BH-SF-LF-0010	Gaining	23	9	15	15.7	3.1	2.2
BH-SF-LF-0010 to BH-SF-LF-0011	Gaining	32	41	28	33.7	NA[b]	NA[b]
		9/9/2008	**9/10/2008**	**9/11/2008**	**3-day Average**	**Model-simulated Previous Calibration**	**Model-simulated Previous Calibration**
Site B-1 ALT to Site B-2 ALT	Losing	-12.7	-14.5	-7.9	-11.7	-3.0	-4.1
Site B-2 ALT to Site B-5 ALT	Gaining	9.1	12.1	8.6	9.9	2.4	3.4
Site B-5 ALT to Site B-7	Losing	-5.5	-9.2	-6.2	-7.0	0.25	0.9
Site B-7 to Site B-8	Gaining	14.9	17.9	15.8	16.2	0.5	0.5

[a]Although the reaches are the same approximate geographic location between the field-measured and simulated data, the exact locations of the transitions between gaining and losing vary slightly.

[b]The change in flow for this reach was not evaluated due to anomalous surface water flow measurements in the western portion of the Box, as noted in the *Technical Report, Osburn Flats Groundwater-Surface Water Interaction Study, Upper Coeur d'Alene Basin, Osburn, Idaho* (CH2M HILL, 2009c).

Notes:

cfs = cubic feet per second

SFCDR = South Fork Coeur d'Alene River

TABLE A-6

Simulated Stream Stage Differences for the 90th Percentile Flow Calibration -- SFCDR Model

Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Stream	Stream Gauge	Stream Stage Difference[a] (feet)
Boulder Creek	None	0.2
Bear Creek	None	0.2
Big Creek	None	0.3
Blackcloud Creek	None	0.2
Bunker Creek	BH-BC-0004	0
Bunker Creek	BH-BC-0005	0.1
Bunker Creek	BH-BC-0006	0.2
Canyon Creek	None	0.3
Cook Creek	None	0.2
Deadman Gulch	None	0.2
Deadwood Gulch	BH-DW-0001	0.2
Dexter Gulch	None	0.2
East Fork Big Creek	None	0.2
East Fork Deadman Gulch	None	0.2
Notes:	None	0.2
East Fork Ninemile Creek	None	0.2
East Fork Pine Creek	None	0.3
East Fork Twomile Creek	None	0.2
East Fork Willow Creek	None	0.2
Elk Creek	None	0.3
Gold Creek	None	0.2
Government Creek	BH-GG-0001	0.3
Government Creek	BH-GG-0002	0.3
Government Creek	BH-GG-0004	0.3
Grouse Creek	BH-GC-0001	0.15
Grouse Gulch	None	0.2
Humboldt Creek	BH-HC-0001	0.3
Italian Gulch	None	0.2
Jackass Creek	None	0.2
Lake Creek	None	0.2
Little North Fork of the South Fork Coeur d'Alene River	None	0.2
Little Pine Creek	None	0.3
Magnet Gulch	BH-MG-0001	0.15
McFarren Culch	None	0.2
Middle Fork Pine Creek	None	0.2
Mill Creek	None	0.2
Milo Creek	None	0.3
Montgomery Creek	None	0.3
Moon Creek	None	0.3
Ninemile Creek	None	0.3
Nuckols Gulch	None	0.2
Pine Creek	None	0.3
Placer Creek	None	0.3
Portal Gulch	None	0.2
Railroad Gulch	None	0.2
Revenue Gulch	None	0.2
Rock Creek	None	0.2
Rosebud Gulch	None	0.2
Ruddy Gulch	None	0.2
SFCDR	SF-268 (Elizabeth Park)	2.1
SFCDR	SF-271 (Pinehurst)	1.6
SFCDR	SF-OB-SG01	1.7
SFCDR	SF-OB-SG02	1.2

TABLE A-6
Simulated Stream Stage Differences for the 90th Percentile Flow Calibration -- SFCDR Model
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Stream	Stream Gauge	Stream Stage Difference[a] (feet)
SFCDR	SF-OB-SG03	1.3
SFCDR	Smelterville	1.6
SFCDR	Theater Bridge	1.6
Shields Gulch	None	0.2
St. Joe Creek	None	0.2
Terror Gulch	None	0.3
Trowbridge Gulch	None	0.2
Twomile Creek	None	0.3
Upper SFCDR Unnamed Tributary	None	0.2
West Fork	None	0.2
West Fork Big Creek	None	0.2
West Fork Deadman Gulch	None	0.2
West Fork Elk Creek	None	0.2
West Fork Montgomery Creek	None	0.2
West Fork Moon Creek	None	0.2
West Fork Pine Creek	None	0.2
West Fork Placer Creek	None	0.2
West Fork Willow Creek	None	0.2
Willow Creek	None	0.2

[a]Stream stage difference is equal to the value measured on April 20, 2009, minus the average value measured between September 22 and October 20, 2008 (the baseflow calibration period).

Note:
SFCDR = South Fork Coeur d'Alene River

TABLE A-7
Monthly Multipliers for Deep Percolation of Precipitation – SFCDR Model
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation Month	Multiplier
July 2008	2.3
August 2008	1.5
September 2008	1.3
October 2008	1
November 2008	1.3
December 2008	1.5
January 2009	1.7
February 2009	1.9
March 2009	2.5
April 2009	2.9
May 2009	3.6
June 2009	2.9

Note:

SFCDR = South Fork Coeur d'Alene River

TABLE A-8

Monthly Multipliers for Deep Percolation of Precipitation – Canyon Creek Model

Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation Month	Multiplier
July 2008	0.1
August 2008	0.02
September 2008	0.01
October 2008	0.01
November 2008	0.02
December 2008	0.025
January 2009	0.05
February 2009	0.05
March 2009	0.1
April 2009	0.15
May 2009	0.2
June 2009	0.15

TABLE A-9

Average Dissolved Zinc Concentrations in Groundwater in Woodland Park, Fall 2006

Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Woodland Park Reach	No Action Average Dissolved Zinc Concentration (mg/L)	Post-Source-Control Average Dissolved Zinc Concentration (mg/L)
Reach 01	1.5	0.4
Reach 02	3.0	2.5
Reach 03	5.2	4.8
Reach 04	19.5	18.3
Reach 05	13.6	13.0
Reach 06	44.3	42.7
Reach 07	14.4	13.9
Reach 08	13.5	13.1
Reach 09	11.1	10.7
Reach 10	12.3	11.3
Reach 11	1.5	1.2
Reach 12	0.5	0.5
SVNRT	124.0	124.0

Notes:

mg/L = milligram(s) per liter

SVNRT = Silver Valley Natural Resource Trust

TABLE A-10

Net Remedial Effectiveness Factors for Woodland Park Source Control Actions

Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Woodland Park Reach	Contaminant Source ID	Proposed Percentage of Total Volume of Material to be Removed	REF from Simplified Tool for Complete Removal	Effective REF Based on Limited Source Removal[a]	Area of Source within Reach (feet^2)	Fraction of Total Source Area within Reach	Fraction of Effective REF	Total REF for Reach
Reach 01	WAL040	72%	99%	71%	1,073,000	0.90	71%	
Reach 01	WAL081	50%	99%	50%	115,270	0.10	50%	69%
Reach 02	WAL040	72%	99%	71%	67,083	0.17	71%	
Reach 02	WAL041	7%	99%	6%	334,300	0.83	6%	17%
Reach 03	WAL041	7%	99%	6%	572,600	1.00	6%	6%
Reach 04	WAL041	7%	99%	6%	450,200	1.00	6%	6%
Reach 05	WAL041	7%	99%	6%	569,400	0.78	6%	
Reach 05	WAL009	0%	0%	0%	165,300	0.22	0%	5%
Reach 06	WAL041	7%	99%	6%	784,500	0.57	6%	
Reach 06	WAL009	0%	0%	0%	506,900	0.37	0%	
Reach 06	WAL042	50%	0%	0%	73,860	0.05	0%	4%
Reach 07	WAL009	0%	0%	0%	332,300	0.45	0%	
Reach 07	WAL041	7%	99%	6%	413,100	0.55	6%	4%
Reach 08	WAL009	0%	0%	0%	344,400	0.55	0%	
Notes:	WAL041	7%	99%	6%	192,900	0.31	6%	
Reach 08	WAL010	7%	99%	7%	92,610	0.15	7%	3%
Reach 09	WAL009	0%	0%	0%	510,900	0.58	0%	
Reach 09	WAL010	7%	99%	7%	364,900	0.42	7%	3%
Reach 10	WAL009	0%	0%	0%	822,800	0.48	0%	
Reach 10	WAL010	7%	99%	7%	392,500	0.23	7%	
Reach 10	OSB047/cc05	21%	99%	20%	411,600	0.24	20%	
Reach 10	WAL011	25%	99%	25%	93,650	0.05	25%	8%
Reach 11	OSB047/cc05	21%	99%	20%	411,600	1.00	20%	20%
Reach 12	None	NA	NA	NA	NA	NA	NA	NA

[a]Effective remedial effectiveness factor (REF) is calculated as the proposed percentage of material to be removed multiplied by the REF from the Simplified Tool.

TABLE A-11
Model-Simulated Flows – Baseflow Conditions
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation	Total SFCDR Gain (cfs)	Total SFCDR Loss (cfs)	Total Bunker Creek Gain (cfs)	Total Bunker Creek Loss (cfs)	Total Government Creek Gain (cfs)	Total Government Creek Loss (cfs)	Total A-4 Drain Gain (cfs)	Total Canyon Creek Gain[a,b] (cfs)	Total Canyon Creek Loss[b] (cfs)	Total Remedial Drain Gain (cfs)
OU 2 No Action	7.8	2.9	0.2	0.8	0.2	0.1	0.4	NA	NA	NA
Alternative (a)	6.6	1.0	0.0	0.1	0.2	0.1	0.2	NA	NA	NA
Alternative (b)	6.8	3.3	0.0	0.0	0.0	0.0	0.4	NA	NA	NA
Alternative (c)	3.5	6.9	0.0	0.0	0.2	0.1	0.1	NA	NA	8.4
Alternative (d)	3.5	6.9	0.0	0.0	0.0	0.0	0.1	NA	NA	8.3
Alternative (e)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	5.2
OU 3 Mainstem SFCDR Watershed Segment 01 - No Action	10.1	8.0	NA	NA	NA	NA	NA	NA	NA	NA
OU 3 Mainstem SFCDR Watershed Segment 01 - Groundwater Actions	0.0	0.0	NA	NA	NA	NA	NA	NA	NA	7.6
OU 3 Woodland Park - No Action	NA	NA	NA	NA	NA	NA	NA	2.1	0.8	NA
OU 3 Updated Remedial Components for Woodland Park	NA	NA	NA	NA	NA	NA	NA	1.6	1.1	1.0

[a]Includes groundwater discharge to Canyon Creek and land surface
[b]Woodland Park Reaches 1 though 12

Notes:
cfs = cubic feet per second
NA = not applicable
OU = Operable Unit
SFCDR = South Fork Coeur d'Alene River

TABLE A-12

Simulated Dissolved Zinc Load – Baseflow Conditions

Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation	Net Load to SFCDR lb/day	Net Load to Bunker Creek lb/day	Net Load to Government Creek lb/day	Net Load to A-4 Drain lb/day	Load to Canyon Creek lb/day	Total Load lb/day	Reduction in Load from No Action lb/day	Load to RA-Drains lb/day
OU 2 No Action	526	15	33	31	NA	605	0	NA
Alternative (a)	462	0	33	18	NA	513	92	NA
Alternative (b)	475	0	0	29	NA	504	101	NA
Alternative (c)	63	0	33	4	NA	100	505	1,073
Alternative (d)	63	0	0	4	NA	67	538	1,065
Alternative (e)	0	0	0	0	NA	0	605	510
OU 3 Mainstem SFCDR Watershed Segment 01 - No Action	66	NA	NA	NA	NA	66	0	NA
OU 3 Mainstem SFCDR Watershed Segment 01 - Groundwater Actions	0	NA	NA	NA	NA	0	66	74
OU 3 Woodland Park - No Action	NA	NA	NA	NA	125	125	0	NA
OU 3 Updated Remedial Components for Woodland Park	NA	NA	NA	NA	41	41	84	82

Notes:

lb/day = pound(s) per day
NA = not applicable
OU = Operable Unit
SFCDR = South Fork Coeur d'Alene River

TABLE A-13
Model-Simulated Flows – 7Q10 Conditions
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation	Total SFCDR Gain (cfs)	Total SFCDR Loss (cfs)	Total Bunker Creek Gain (cfs)	Total Bunker Creek Loss (cfs)	Total Government Creek Gain (cfs)	Total Government Creek Loss (cfs)	Total A-4 Drain Gain (cfs)	Total Canyon Creek Gain[a,b] (cfs)	Total Canyon Creek Loss[b] (cfs)	Total Remedial Drain Gain (cfs)
OU 2 No Action	7.1	3.5	0.2	0.9	0.1	0.2	0.3	NA	NA	NA
Alternative (a)	5.7	1.4	0.0	0.1	0.1	0.2	0.1	NA	NA	NA
Alternative (b)	6.7	3.6	0.0	0.0	0.0	0.0	0.3	NA	NA	NA
Alternative (c)	2.8	7.6	0.0	0.0	0.1	0.2	0.0	NA	NA	8.2
Alternative (d)	3.3	6.5	0.0	0.0	0.0	0.0	0.1	NA	NA	8.6
Alternative (e)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	4.0
OU 3 Mainstem SFCDR Watershed Segment 01 - No Action	9.4	8.4	NA	NA	NA	NA	NA	NA	NA	NA
OU 3 Mainstem SFCDR Watershed Segment 01 - Groundwater Actions	0.0	0.0	NA	NA	NA	NA	NA	NA	NA	6.3
OU 3 Woodland Park - No Action	NA	NA	NA	NA	NA	NA	NA	1.7	1.1	NA
OU 3 Updated Remedial Components for Woodland Park	NA	NA	NA	NA	NA	NA	NA	1.1	1.2	0.8

[a]Includes groundwater discharge to Canyon Creek and land surface.
[b]Woodland Park Reaches 1 though 12

Notes:
cfs = cubic feet per second
NA = not applicable
OU = Operable Unit
SFCDR = South Fork Coeur d'Alene River

TABLE A-14
Simulated Dissolved Zinc Load – 7Q10 Conditions
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation	Net Load to SFCDR lb/day	Net Load to Bunker Creek lb/day	Net Load to Government Creek lb/day	Net Load to A-4 Drain lb/day	Load to Canyon Creek lb/day	Total Load lb/day	Reduction in Load from No Action lb/day	Load to RA-Drains lb/day
OU 2 No Action	502	11	14	25	NA	553	0	NA
Alternative (a)	425	0	14	12	NA	450	103	NA
Alternative (b)	477	0	0	28	NA	505	48	NA
Alternative (c)	43	0	14	1	NA	58	495	1,045
Alternative (d)	61	0	0	11	NA	72	481	1,095
Alternative (e)	0	0	0	0	NA	0	553	398
OU 3 Mainstem SFCDR Watershed Segment 01 - No Action	58	NA	NA	NA	NA	58	0	NA
OU 3 Mainstem SFCDR Watershed Segment 01 - Groundwater Actions	0	NA	NA	NA	NA	0	58	61
OU 3 Woodland Park - No Action	NA	NA	NA	NA	101	101	0	NA
OU 3 Updated Remedial Components for Woodland Park	NA	NA	NA	NA	26	26	75	53

Notes:
lb/day = pound(s) per day
NA = not applicable
OU = Operable Unit
SFCDR = South Fork Coeur d'Alene River

TABLE A-15
Model-Simulated Flows – 90th Percentile Flow Conditions
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation	Total SFCDR Gain (cfs)	Total SFCDR Loss (cfs)	Total Bunker Creek Gain (cfs)	Total Bunker Creek Loss (cfs)	Total Government Creek Gain (cfs)	Total Government Creek Loss (cfs)	Total A-4 Drain Gain (cfs)	Total Canyon Creek Gain[a,b] (cfs)	Total Canyon Creek Loss[b] (cfs)	Total Remedial Drain Gain (cfs)
OU 2 No Action	6.0	3.7	0.5	0.4	0.5	0.1	0.5	NA	NA	NA
Alternative (a)	5.6	1.2	0.0	0.1	0.5	0.1	0.5	NA	NA	NA
Alternative (b)	5.7	3.8	0.0	0.0	0.0	0.0	0.5	NA	NA	NA
Alternative (c)	2.6	8.0	0.0	0.0	0.5	0.1	0.2	NA	NA	9.4
Alternative (d)	2.9	7.2	0.0	0.0	0.0	0.0	0.4	NA	NA	9.8
Alternative (e)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	NA	NA	10.8
OU 3 Mainstem SFCDR Watershed Segment 01 - No Action	9.9	9.5	NA	NA	NA	NA	NA	NA	NA	NA
OU 3 Mainstem SFCDR Watershed Segment 01 - Groundwater Actions	0.0	0.0	NA	NA	NA	NA	NA	NA	NA	8.0
OU 3 Woodland Park - No Action	NA	NA	NA	NA	NA	NA	NA	4.5	0.4	NA
OU 3 Updated Remedial Components for Woodland Park	NA	NA	NA	NA	NA	NA	NA	3.7	0.7	1.5

[a]Includes groundwater discharge to Canyon Creek and land surface.
[b]Woodland Park Reaches 1 though 12

Notes:
cfs = cubic feet per second
NA = not applicable
OU = Operable Unit
SFCDR = South Fork Coeur d'Alene River

TABLE A-16
Simulated Dissolved Zinc Load – 90th Percentile Flow Conditions
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation	Net Load to SFCDR lb/day	Net Load to Bunker Creek lb/day	Net Load to Government Creek lb/day	Net Load to A-4 Drain lb/day	Load to Canyon Creek lb/day	Total Load lb/day	Reduction in Load from No Action lb/day	Load to RA-Drains lb/day
OU 2 No Action	561	42	57	54	NA	715	0	NA
Alternative (a)	516	0	57	52	NA	625	90	NA
Alternative (b)	545	0	0	60	NA	605	110	NA
Alternative (c)	86	0	57	22	NA	165	550	1,303
Alternative (d)	123	0	0	40	NA	163	552	1,350
Alternative (e)	0	0	0	30	NA	30	685	1,213
OU 3 Mainstem SFCDR Watershed Segment 01 - No Action	58	NA	NA	NA	NA	58	0	NA
OU 3 Mainstem SFCDR Watershed Segment 01 - Groundwater Actions	0	NA	NA	NA	NA	0	58	77
OU 3 Woodland Park - No Action	NA	NA	NA	NA	258	258	0	NA
OU 3 Updated Remedial Components for Woodland Park	NA	NA	NA	NA	112	112	146	182

Notes:
lb/day = pound(s) per day
NA = not applicable
OU = Operable Unit
SFCDR = South Fork Coeur d'Alene River

TABLE A-17

Model-Simulated Flows – Average Annual Conditions

Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation	Total SFCDR Gain (cfs)	Total SFCDR Loss (cfs)	Total Bunker Creek Gain (cfs)	Total Bunker Creek Loss (cfs)	Total Government Creek Gain (cfs)	Total Government Creek Loss (cfs)	Total A-4 Drain Gain (cfs)	Total Canyon Creek Gain[a,b] (cfs)	Total Canyon Creek Loss[b] (cfs)	Total Remedial Drain Gain (cfs)
OU 2 No Action	7.2	2.9	0.2	0.9	0.3	0.1	0.4	NA	NA	NA
Alternative (a)	6.0	1.5	0.0	0.1	0.3	0.1	0.3	NA	NA	NA
Alternative (b)	6.4	3.3	0.0	0.0	0.0	0.0	0.4	NA	NA	NA
Alternative (c)	3.2	7.3	0.0	0.0	0.3	0.2	0.1	NA	NA	8.8
Alternative (d)	3.2	7.3	0.0	0.0	0.0	0.01	0.1	NA	NA	8.7
Alternative (e)	0	0	0	0	0	0	0.0	NA	NA	5.3
OU 3 Mainstem SFCDR Watershed Segment 01 - No Action	10.8	7.0	NA	NA	NA	NA	NA	NA	NA	NA
OU 3 Mainstem SFCDR Watershed Segment 01 - Groundwater Actions	0.0	0.0	NA	NA	NA	NA	NA	NA	NA	8.0
OU 3 Woodland Park - No Action	NA	NA	NA	NA	NA	NA	NA	2.8	0.6	NA
OU 3 Updated Remedial Components for Woodland Park	NA	NA	NA	NA	NA	NA	NA	2.1	0.9	1.2

[a]Includes groundwater discharge to Canyon Creek and land surface.

[b]Woodland Park Reaches 1 though 12

Notes:

cfs = cubic feet per second

NA = not applicable

OU = Operable Unit

SFCDR = South Fork Coeur d'Alene River

TABLE A-18
Simulated Dissolved Zinc Load – Average Annual Conditions
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Simulation	Net Load to SFCDR lb/day	Net Load to Bunker Creek lb/day	Net Load to Government Creek lb/day	Net Load to A-4 Drain lb/day	Load to Canyon Creek lb/day	Total Load lb/day	Reduction in Load from No Action lb/day	Load to RA-Drains lb/day
OU 2 No Action	524	14	38	42	NA	617	0	NA
Alternative (a)	447	-0.5	37	26	NA	509	108	NA
Alternative (b)	480	0	0	37	NA	517	100	NA
Alternative (c)	64	0	36	7	NA	107	510	1,163
Alternative (d)	64	0	0	6	NA	70	547	1,146
Alternative (e)	0	0	0	0	NA	0	617	531
OU 3 Mainstem SFCDR Watershed Segment 01 - No Action	77	NA	NA	NA	NA	77	0	NA
OU 3 Mainstem SFCDR Watershed Segment 01 - Groundwater Actions	0	NA	NA	NA	NA	0	77	77
OU 3 Woodland Park - No Action	NA	NA	NA	NA	141	141	0	NA
OU 3 Updated Remedial Components for Woodland Park	NA	NA	NA	NA	53	53	87	117

Notes:
lb/day = pound(s) per day
NA = not applicable
OU = Operable Unit
SFCDR = South Fork Coeur d'Alene River

TABLE A-19
Results of the OU 2 Sensitivity Analysis
Focused Feasibility Study, Upper Basin of the Coeur d'Alene River, Bunker Hill Superfund Site

Input Parameter Modification	Estimated Dissolved Zinc Load to the Surface Water System within the Bunker Hill Box (lb/day)					
	No Action	Alternative (a)	Alternative (b)	Alternative (c)	Alternative (d)	Alternative (e)
Calibrated Baseflow Model	605	513	504	100	67	0
Kx Bedrock x 10	625	541	514	115	70	11
Kx Bedrock x 100	684	628	568	140	93	14
Kx Bedrock ÷ 10	600	507	502	97	66	11
Kx Bedrock ÷ 100	600	506	502	96	66	11
Kx CU x 10	605	513	504	100	67	12
Kx CU x 100	605	511	503	101	67	11
Kx CU ÷ 10	605	513	504	100	67	13
Kx CU ÷ 100	605	513	504	100	67	13
Kx Alluvium x 5	1,026	863	849	278	260	20
Kx Alluvium x 10	1,341	1,120	1,117	498	491	31
Kx Alluvium ÷ 5	433	384	371	63	32	8
Kx Alluvium ÷ 10	394	353	336	56	26	7
PPN x 25%	615	527	522	107	69	13
PPN x 50%	624	539	515	114	72	13
PPN ÷ 25%	593	498	498	91	64	12
PPN ÷ 50%	581	481	492	82	61	12
Vertical Resistance x 10	390	341	284	77	44	2
Vertical Resistance x 100	303	245	191	66	31	0
Vertical Resistance ÷ 10	726	594	604	115	82	7
Vertical Resistance ÷ 100	774	621	636	123	91	11
SFCDR wc1 x 5	358	316.0	274	100	66	13
SFCDR wc1 x 10	277	241	195	101	65	13
SFCDR wc1 ÷ 5	679	563	562	100	66	11
SFCDR wc1 ÷ 10	688	571	670	101	68	13
SFCDR Stream Stage - 1 foot	647	540	530	122	89	13
SFCDR Stream Stage - 2 feet	680	558	537	145	111	13
SFCDR Stream Stage + 1 foot	540	464	448	74	41	13
SFCDR Stream Stage + 2 feet	447	384	364	41	8	13

Notes:
CU = confining unit
Kx = horizontal hydraulic conductivity
PPN = calibrated deep percolation of precipitation distribution
wc1 = streambed conductance term